1987

Pumping-erosion subidence of a seafloor plate-footing.

Grimmig, Alvin E., Jr.

PUMPING-EROSION SUBIDENCE
OF A SEAFLOOR PLATE-FOOTING

AN ENGINEEERING REPORT

OCEN 685
by

ALVIN E. GRIMMIG JR.

LT, CEC, USN

Submitted to the Graduate College of
Texas A&m University
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Approved as to style and content by:

John B. Herbich
(Chairman)

Wayne A. Dunlap
(Member)

Wilfred Gardner
(Member)

NOVEMBER 1987

ABSTRACT

PUMPING-EROSION SUBSIDENCE

OF A SEAFLOOR PLATE-FOOTING

(November 1987)

ALVIN EUGENE GRIMMIG JR., B.S. University of Washington

Chairman of Advisory Committee: Dr. John B. Herbich

Subsidence of objects that rest on the seafloor is an expected but not well understood phenomenon. Subsidence is the settlement of fixed structures and mobile structures (such as oceanographic packages) that are placed on the seafloor. A major concern involving bottom resting systems, in relatively shallow water (less than 200 meters) is wave induced motions. The system response of the structure in this dynamic environment can create substantial loadings at the structure-seafloor interface. Past works have addressed wave-induced and current scour as the major factors causing structural subsidence, neglecting the effects of pumping - erosion.

The research described is directed towards indentifying and understanding the phenomenological aspects of pumping-erosion. The work describes a new hypothesis concerning liquefaction as being the precursor to subsidence in a two cycle pumping-erosion process. Due to the complexity of

structure-soil interaction a multivariable linear regression was performed on the data to substantiate experimental observations.

ACKNOWLEDGEMENTS

The author is grateful to Dr. John B. Herbich, for serving as his Committee Chairman. Appreciation is also extended to Dr. Wayne Dunlap and Dr. Wilfred Gardner for their role as Committee Members and for their advice, interest and encouragement. A special thanks to Dr. Robert Randall, for his perspective and encouragement.

I am especially grateful to wife, Debra and sons Matt, Andy and Aaron, for their continuous love, faith and support during this course of study. In appreciation, I dedicate this work to them.

Thanks is also extended to technicians Randy Bush, Charles Carnes, and Carl Fredrickson for their assistance in the development and operation of equipment during research.

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CHAPTER I

INTRODUCTION

Structural subsidence can range from a few inches to several feet causing results varying from slight tilting and displacements of a structure to total and catastrophic structural failure. As a result of the petroleum and gas industries use of seafloor supported structures (i.e. jack-up rigs) much investigation has been directed at the structure-soil system and interaction. Although this area has been intensely investigated, the focus of attention has been on large oil rig structures.

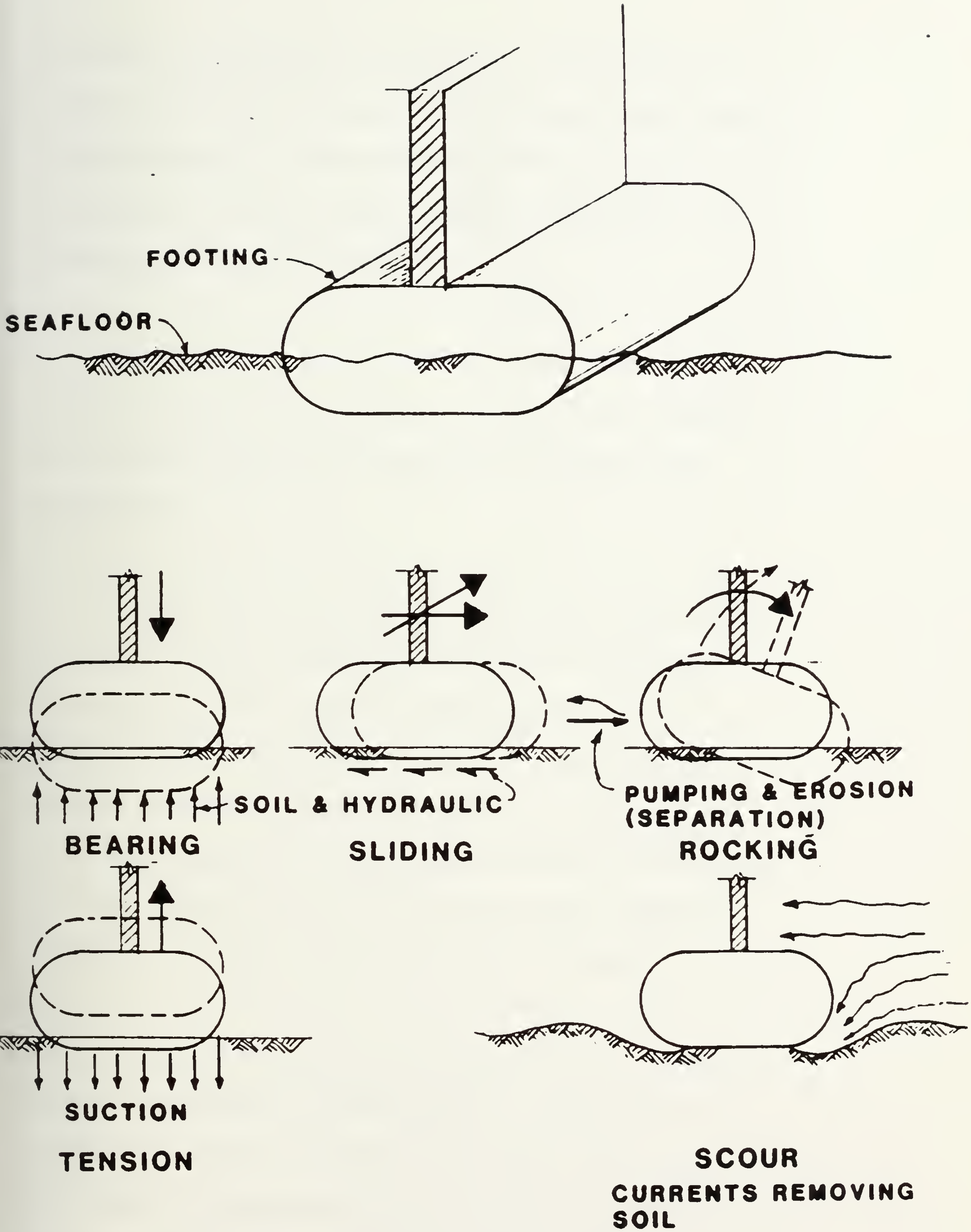
The use of relatively small mobile submerged structures for oceanographic and industrial purposes has increased in the past several years. The ability to successfully deploy, operate and retrieve these instruments and equipment packages is largely dependent upon the structure-seafloor interaction. Bottom resting systems are subject to the dynamic response of the structure in the ocean regime which can produce significant dynamic loadings at the seafloor. The stability of a submerged seafloor structure is dependent upon the subsidence and orientation of the structure while subject to wave and current forces. These forces produce a footing response in a variety of bearing, tension, sliding,

rocking and torsional strains in the marine soil supporting the structure (Figure 1).

The central issue of this report involves the investigation of the phenomenon and mechanisms of pumping-erosion and its contribution to subsidence. Pumping-erosion is inherently non-linear as the structure is intermittently coupled and decoupled from the soil interface. In addition, the effects of the period of oscillation, amplitude of displacement, footing characteristics, hydrodynamic effects and soil parameters are simultaneously involved resulting in a very complicated and complex problem.

The basic pumping-erosion cycle involves an uplifting force vertically displacing the footing off the seafloor. Subsequently, a downward force will dynamically load the structure onto the soil again. This over simplified cycle is a Trojan horse, as it involves several discrete and intertwined forces which are not readily apparent.

Consideration must be given to the geometry and dynamics of the footing, The size, shape, and weight of the structure will determine such characteristics as center of mass, center of buoyancy, drag and lift forces and moments of inertia which will determine the structures response to the exciting force. The wave and current environment will produce the exciting force characteristics of period,



FOOTING RESPONSES

FIGURE 1

amplitude, and duration of excitation. Hydrodynamically, effects of exit and entrance velocities, water density and viscosity as well as the added mass of the interacting structure will influence the structure response and the sediment transport and settlement.

Soil parameters such as soil density, permeability, void ratio, grain size and shape, and pore water pressures will determine seafloor response to the structure-soil interaction.

Traditionally subsidence was attributed to the effects of scour resulting from the driving force of wave and currents with little regard to pumping-erosion. Any inference to pumping-erosion usually surrounds the latter half cycle where the water is displaced or "pumped" from under the footing as it makes contact with the soil surface. The soil transport has been attributed to the "jetting" action of the water escaping from under the footing.

But what of the first half of the cycle of the footing when it is uplifted from the seafloor ? What forces are involved ? And what contributions do these forces make to the process of subsidence ? As the footing is uplifted, negative pore water pressures can be developed in the soil under the footing, possibly to the point of liquefaction.

Liquefaction, or fluidization, occurs when the pore-water pressure in a soil is equivalent to the total stress of the soil; in other words when the effective strength of the soil equals zero. Liquefaction of a soil requires considerable pore water pressures as compared to the relative ease of fluidization, which reduces the effective strength of the soil by the increase in the pore water pressure combined with the uplifting effect of the upward seepage flow. If the bed is considered deformable, the fluidization would then weaken the grain skeleton and distort the grain bed surface causing the grains to have a greater hydraulic profile making them readily available for transport during the downward half cycle of the footing.

Thus, it is hypothesized that subsidence is a two phase cycle. The first phase occurs on the uplifting of the footing causing sufficient negative pore water pressures to fluidize the bed which weakens and distorts the bed making the upper grain layers more susceptible to sediment transport. The second phase, occurs on the downward stroke of the footing where the velocities developed under the footing transport the sediment. The transport to the sediment will be accentuated at the edges where the water is jetted out from under the footing. The following research is designed to investigate the hypothesis on a phenomenological basis.

OBJECTIVES

The objectives of this research are as follows:

1. To determine which geometric, hydrodynamic and kinematic parameters are involved in pumping-erosion subsidence.

2. To evaluate the relative importance of the geometric, fluid and kinematic parameters involved in pumping-erosion subsidence.

3. To determine if sufficient negative pore water pressures can be developed under the footing to fluidize the foundation bed to the point of liquefaction.

CHAPTER II

LITERATURE REVIEW

There are a limited number of references dealing with soil/water/structure interaction. Even fewer address the soil/water/structure interactions and forces involved in structural subsidence. Furthermore, there are only two sited works that discuss the topic of pumping-erosion. Most structural subsidence is attributed to he effects of scour. Herbich et al.(3) has compiled an extensive biography on the topic of conventional scour.

Reimnitz and Kempema (10) in 1981, describes the effects of dynamic ice wallowing in the Alaskan nearshore areas. The report hypothesizes the occurence oftwo types of hydraulic processes. In the first process the ice plays a passive role, acting as a flow obstacle in the current and wave regime. This particular aspect would account for the more conventional scour around structures. The second hydraulic process involves ice playing an active role, either by simple vertical oscillations or by wallowing (rocking). Dahlberg (1) discusses pumping erosion as it pertains to structures. He states that pumping erosion is associated with excess pore-water pressures set-up in the foundation soil during storm periods. Dalhberg suggests

that excess pore-water pressures develop to balance the overturning moments on the base of the structure. It is further stated that if there is free communication between the foundation soil and the seabed, the pore-water gradient may be high enough to liquefy the soil locally.

It was verified that a North Sea platform, Frigg CDP1, which had no protective scour skirts, was subject to pumping-erosion. Divers observed periodic puffs of sediment around the periphery of the structure base when the sediments were carried in suspension as the structure rocked in the storm environment. It is noted that the pumping-erosion described was solely attributed to the positive pore-water pressures escaping above the mudline due to the pressure gradient.

An extreme case of pumping-erosion involved the Christchurch Bay Tower located in 8.4 meters of water. The platform was subject to severe storm conditions. Due to the absence of protective scour skirts the platform was undermined by scour, which lead to a free rocking motion of the structure, resulting in pumping-erosion on the foundation soil.

Pumping-erosion of gravity structures is now rare,due to their size and the use of scour skirts. Most settlement

of gravity structures, as described by DiBiagio (2), is attributed to consolidation settlement.

Teramoto et al. (13) discussed the scour encountered with various sit-on-bottom type of structures. The study investigates the various scour patterns and contours for various footing designs and configurations.

However, pumping erosion is more applicable to lightweight mobile structures (i.e. oceanographic research instrumentation packages which can be deployed from research vessels) and is the focus of this topic.

Several works have dealt with wave induced pore water pressures. Approaches have varied from considering the soil skeleton to be rigid, to being compressible and pore water as being compressible or incompressible. Governing equations were usually derived from Darcy's Law of flow through a permeable bed or Biot's Law for three dimensional consolidation for a poro-elastic material. In addition, various studies have evaluated whether residual pore-water pressures exist in cohesionless soils or whether the pore pressures are merely transient.

Oldinziel and Brink (9), indicate that an upward flow of water through a porous sand bed reduces the apparent weight of the sand particles and therefore reduces the sand

particles' stability. The results of the study conclude that upward flow (blowing) through the bed increases the rate of sediment transport. The study relates the upward blowing forces to pressure gradients in the bed that depend on seepage velocities as defined by Darcy's Law.

Martin and Aral(5), 1971, indicates that the seepage force on a surface grain is only 50% of that for an embedded grain. However, the study concludes that it is clear that upward seepage will reduce the stability of surface grains, whereas the downward seepage will increase stability. Martin (4) in 1974, demonstrated that bed failure could also result from a horizontal pressure gradient.

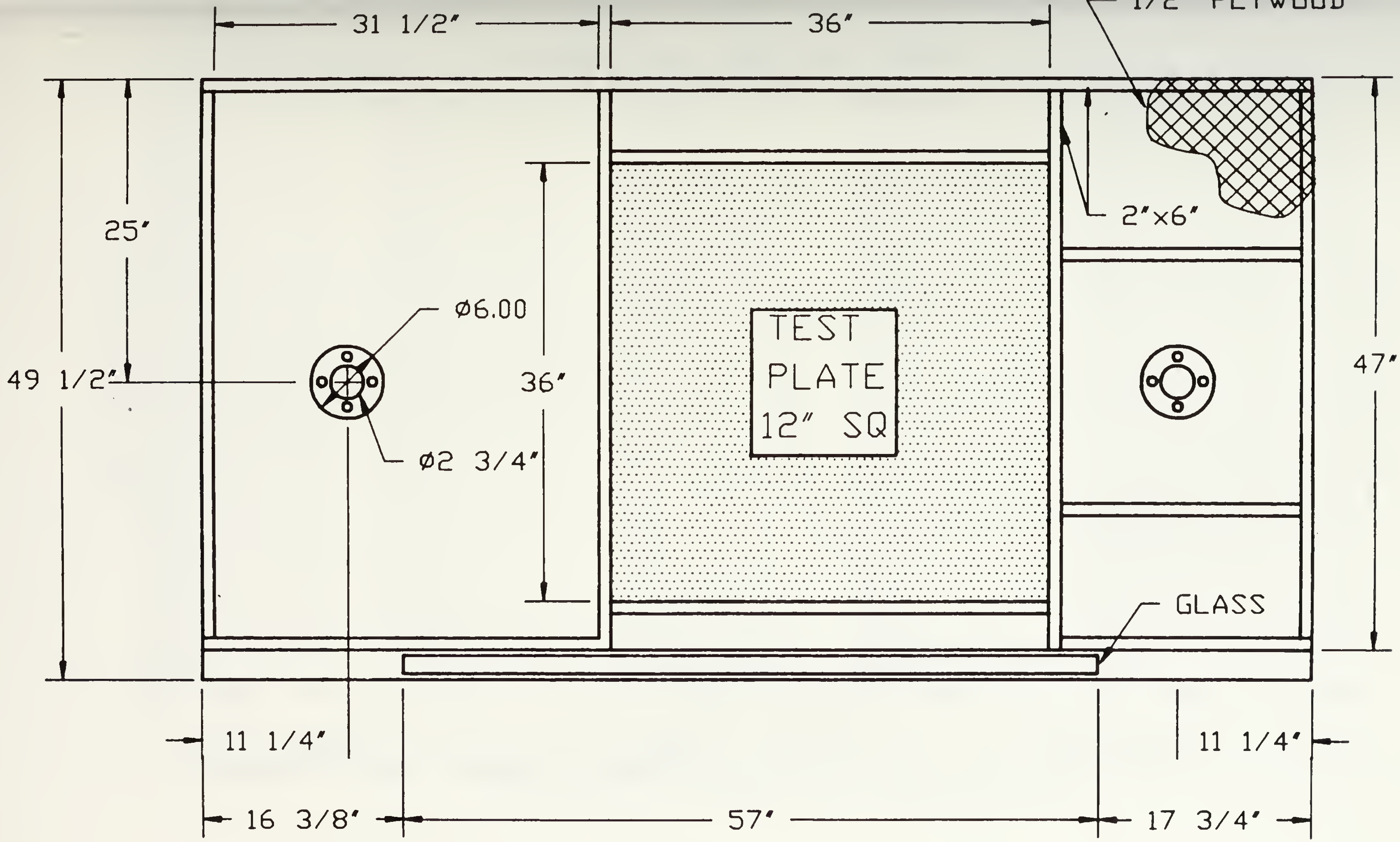
CHAPTER III

PROCEDURES AND INSTRUMENTATION

When non-fixed seafloor systems are subjected to wave and current forces of sufficient levels, the structure will oscillate. The wave pressure forces, in conjunction with the current forces will lift the structure and then will load it again on the seafloor. The response of the structure and subsequent subsidence are a function of several geometric, hydrodynamic and kinematic factors.

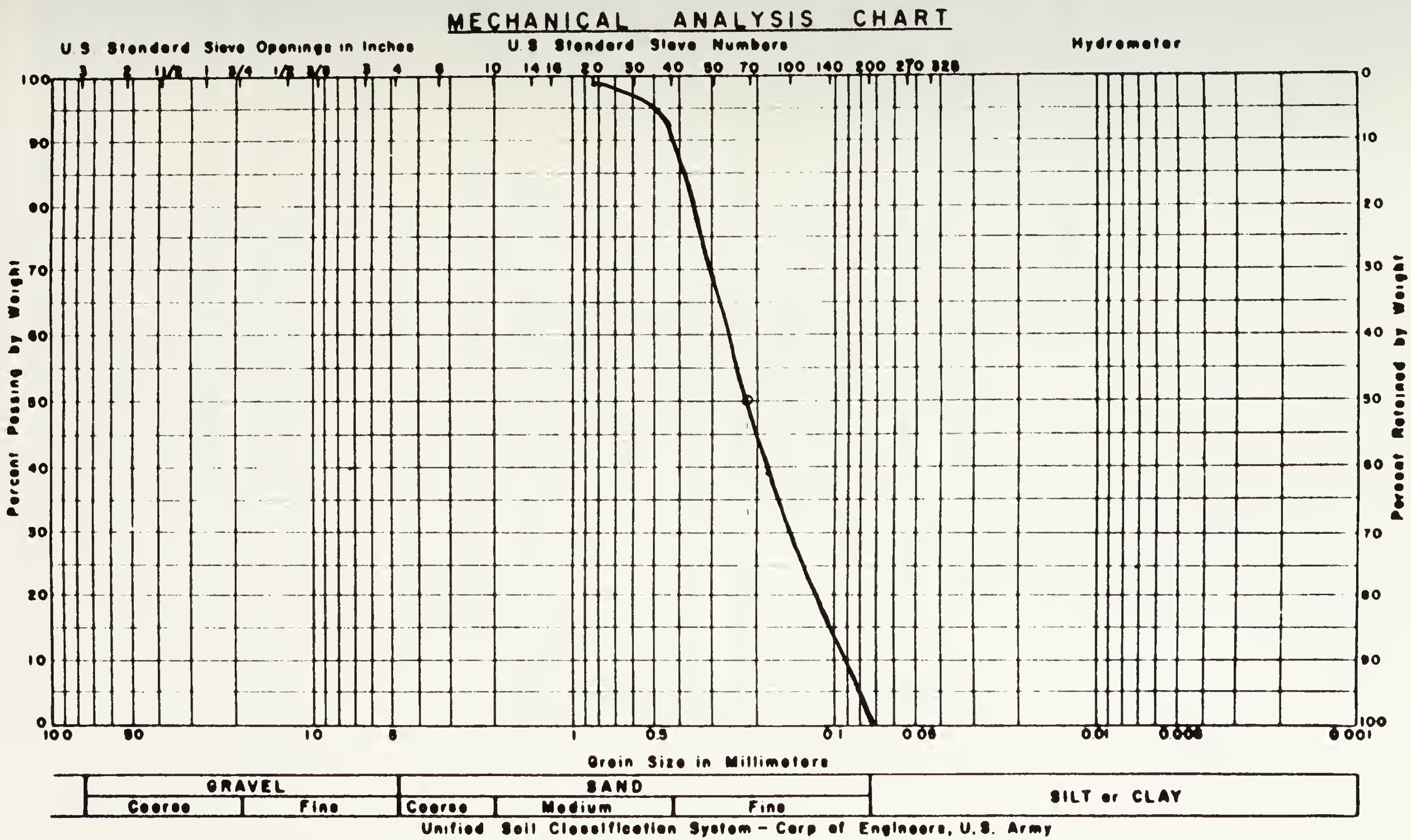
Due to the amount of limited data concerning pumping-erosion subsidence a simple plate type footing employing purely vertical oscillations was chosen. The tests were conducted in a steel tank with a glass observation window. The dimensions of the tank were 8 feet long, 4 feet wide and 4 feet deep. The glass observation window was 57 inches long and 3/4 inches thick. A sand bed, 11.5 inches deep was placed in the steel tank. The test section (4 feet by 4 feet) was 11.5 inches deep. The remainder of the tank had 5.5 inches of sand overlying a false bottom (Figure 2).

The sand utilized for the test was an Ottawa sand with a specific gravity of 2.65 and a mean grain diameter (d50) of .22mm (0.087 inches) (Figure 3). The sand had a static (pluivated) submerged angle of repose of 16.5o.



Sediment Test Tank
w/False Bottoms

FIGURE 2



d50 = .22 mm

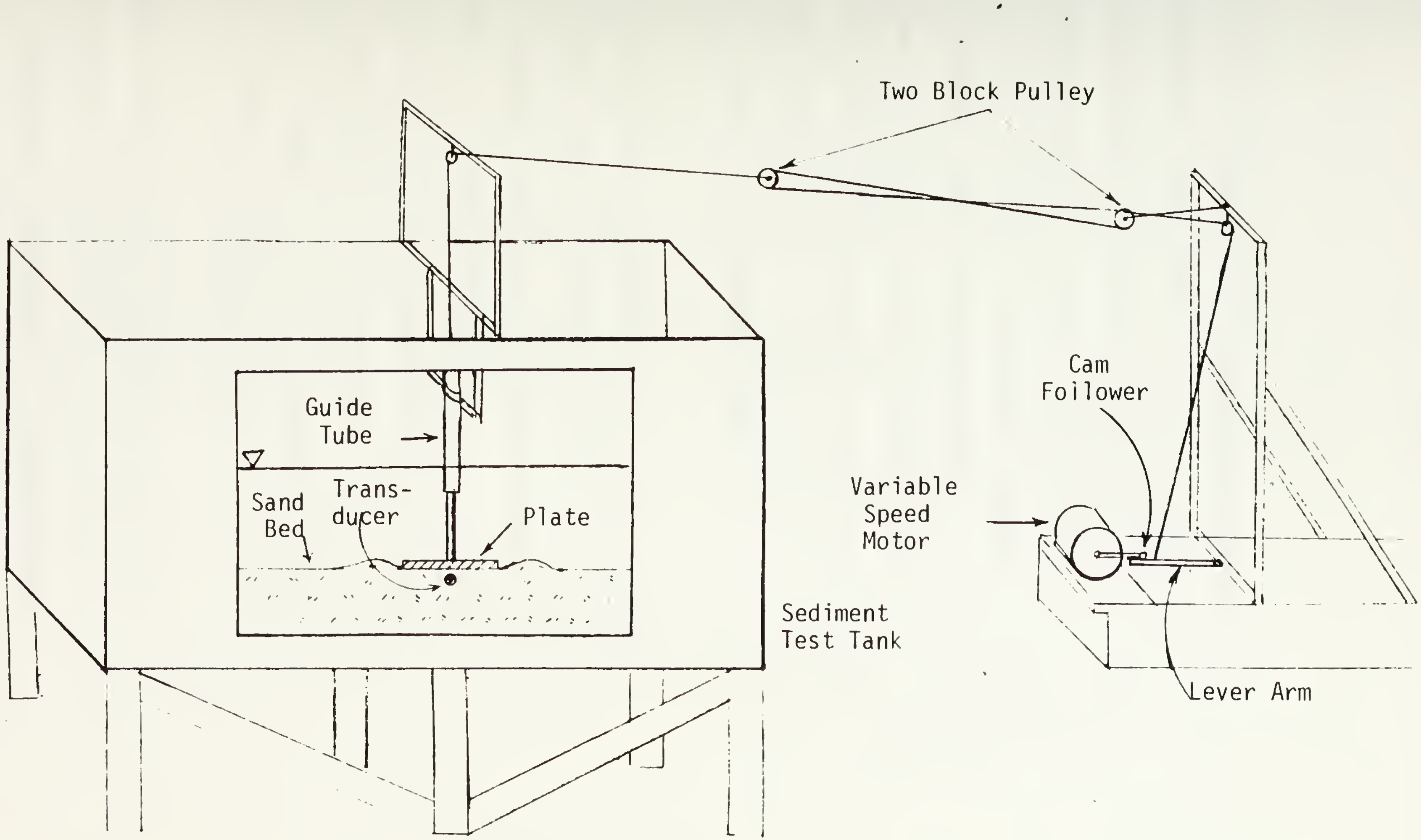
FIGURE 3

Two steel plates were utilized in the experiments. A 12 inch square plate (1 square foot), 3/4 inch, 25 pound plate was utilized for experiments 1 through 6. A 10 gauge (0.132 inch) thick, 16.97 inch square (2 square feet) plate attached to the 1 square foot plate was utilized for the experiments 7 through 12.

The plate was uplifted by a cable and pulley system coupled to a 1/2 horsepower D.C. variable speed motor via a rotating cam follower that engaged lever arm attached to the cable (Figure 4). This particular arrangement allowed the plate to be uplifted from the sandbed to a predetermined amplitude and then the plate was released and allowed to free fall onto the test bed. The next cycle would engage the cam follower on the lever arm lifting the plate again, repeating the cycle. The plate was thus able to follow the contours of the scour caused by the pumping-erosion.

The amplitude of oscillation (1 or 0.8 inches) was obtained by eccentrically locating the cam follower from the center of rotation of the motor shaft. The selection of the amplitudes was restricted by equipment limitations.

Oscillation periods of 5, 10 and 20 seconds were selected to simulate general storm wave conditions that might be experienced by seafloor systems.



EXPERIMENTAL SET-UP

FIGURE 4

Pore-water pressures in the test bed were measured by a Statham P-22S-350 bi-directional pressure transducer (2 psid). The transducer was placed outside of the tank at the same equivalent hydrostatic depth as the sand bed. The transducer detected pressure fluctuations through the active port via a 1/8 inch clear PVC tubing coupled to a needle shaped copper probe fitted with a # 200 mesh screen to restrict the entrance of sand particles into the transducer port. The transducer probe was centered under the plate-footing at a depth of 0.276 inches (7mm).

To insure proper measurements, the active transducer port, PVC tubing, brass coupling and sensing probe were thoroughly cleaned with a strong detergent to remove any dirt, grease or oil that may have accumulated. After rinsing, the active pressure port and extensions were carefully flushed and filled with de-aired water. This procedure was followed to eliminate the possibility of entrapped air within the pressure sensing system.

A static load test was utilized to calibrate the pressure transducer. Readings were taken with the transducer submerged in still water at a predetermined depth. At a second predetermined depth readings were taken again. Since the pressure relationship is a linear, an average calibration factor of 0.043 psi/mv was obtained.

The 5 volt D.C. excitation voltage was supplied by a HP17403A pre-carrier amplifier. The output was recorded by a HP7402A dual channel strip chart recorder.

To record the near bed shear velocities at the plate edge, a Thermo-Systems Inc (TSI), hot film anemometer system was employed. The voltage output of the anemometer is proportional to heat loss across the cylindrical filament (film) as a result of the fluid flow across the filament. The actual velocities were determined from calibration curves developed prior to each experiment.

The calibration was performed by attaching the hot film probe to a motorized trolley carriage which rode on a rail system above a 120 foot wave flume. The carriage was operated at several different speeds over a predetermined distance. The voltage output from the TSI anemometer monitor was displayed on a Beckman 200 digital voltmeter and recorded. A calibration curve of millivolts versus ft/sec was thus developed. Temperature corrections based on Reynolds Number similarities were employed to compensate for the difference in water temperatures between the wave flume and the test tank.

The upward plate velocities (VPU) and the downward plate velocities (VPD) were determined from the hot-film anemometer velocity record.

The scour depth readings were recorded manually by observing a marker attached to a stanchion affixed to the plate traveling across a stationary rule. Horizontal deflections were minimized by extending a guide tube over the square tubing shaft welded to the plate surface.

Twelve experiments were conducted at various combinations of period (T), amplitude of oscillation (A), and plate dimensions (area (AP); weight (W); and thickness (T)).

CHAPTER IV

EXPERIMENTAL RESULTS

A total of 14 experiments were conducted. Two preliminary experiments were performed to observe the effects of the transducer probe position under the plate. As one might expect, the highest negative pore-water pressures were recorded at the center of the plate. Therefore, the center of the plate was chosen for the probe placement. It was the goal of these experiments to obtain a general understanding of the mechanisms involved in the phenomenon of pumping-erosion. The experiments were also designed to investigate whether negative pore-water pressures and possible fluidization of the foundation bed played a significant role in pumping-erosion. Therefore, it was necessary to discern the effects of the experimental parameters in pumping-erosion subsidence. Following is a table listing the controlled variables for each test run:

TABLE 1 - Controlled Parameters

EXP NO.	PERIOD (T) sec.	AMPLITUDE (A) inches	PLATE AREA (AP) ft2	PLATE WEIGHT (W) lbs	PLATE THICKNESS (TH) inches
1	10	1	1	25	.75
2	20	1	1	25	.75
3	5	1	1	25	.75
4.	20	1	1	25	.75
5.	10	1	1	25	.75
6.	5	1	1	25	.75
7.	..20	2	.80	36	.132
8.	10	2	.80	36	.132
9.	5	2	.80	36	.132
10.	20	2	.80	36	.132
11.	10	2	.80	36	.132
12.	5	2	.80	36	.132

The soil used was an Ottawa sand with a mean grain diameter of .22mm. The average bed density of the foundation bed (the area directly under the plate) was 3.30 slugs/ft3. In addition the controlled parameters listed in Table 1, the following variables were also recorded: number of cycles(CYCS), positive pore water pressures (PPWP), negative pore water pressures (PPWS), plate exit velocities

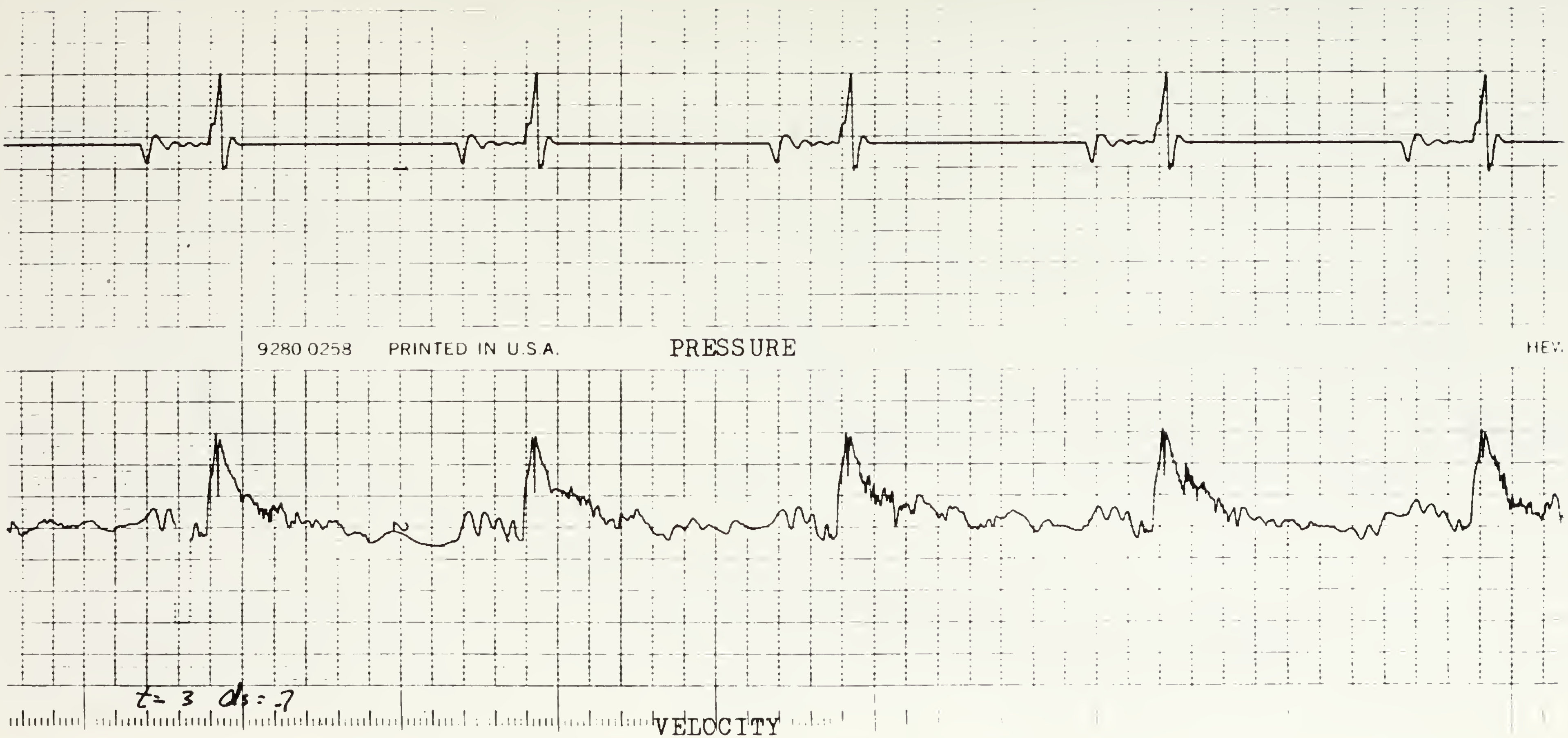
(VE), plate upward velocities (VPU), and plate downward velocities (VPD).

Figures 1 through 12 in Appendix A plot the subsidence versus time and cycles. Figures 13 through 24 plot the subsidence versus the log of time and cycles.

Figures 25, 26 and 27 are group plots of subsidence versus cycles and Figures 28, 29 and 30 are group plots of subsidence versus time for the periods of 5, 10 and 20 seconds respectively. Figure 31, plots the subsidence curves versus cycles (Figure 32 versus time) for the first six experiments (1 sf plate). Figure 33, plots the subsidence versus cycles (Figure 34 versus time) for the last six experiments (2 sf plate).

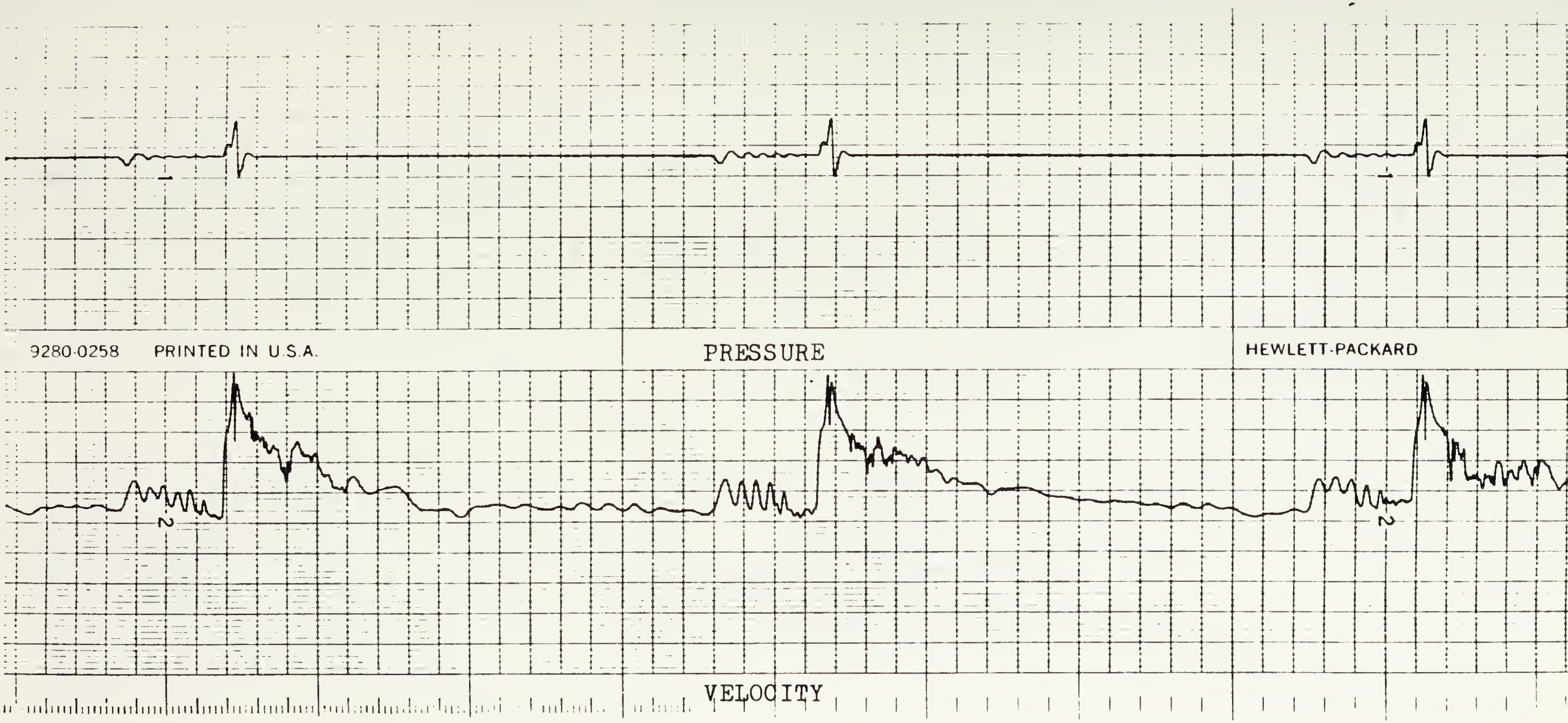
Figures 5A through 5L show typical strip chart output records for the 12 experiments. The pore water pressure record output is recorded on channel 1 and the hot film anemometer output record on channel 2.

As noted in the experimental record, in Appendix B, the output of the hot film anemometer became unreliable as the water temperature increased above 86oF. Thus VE was not considered in the analysis described in Chapter V.



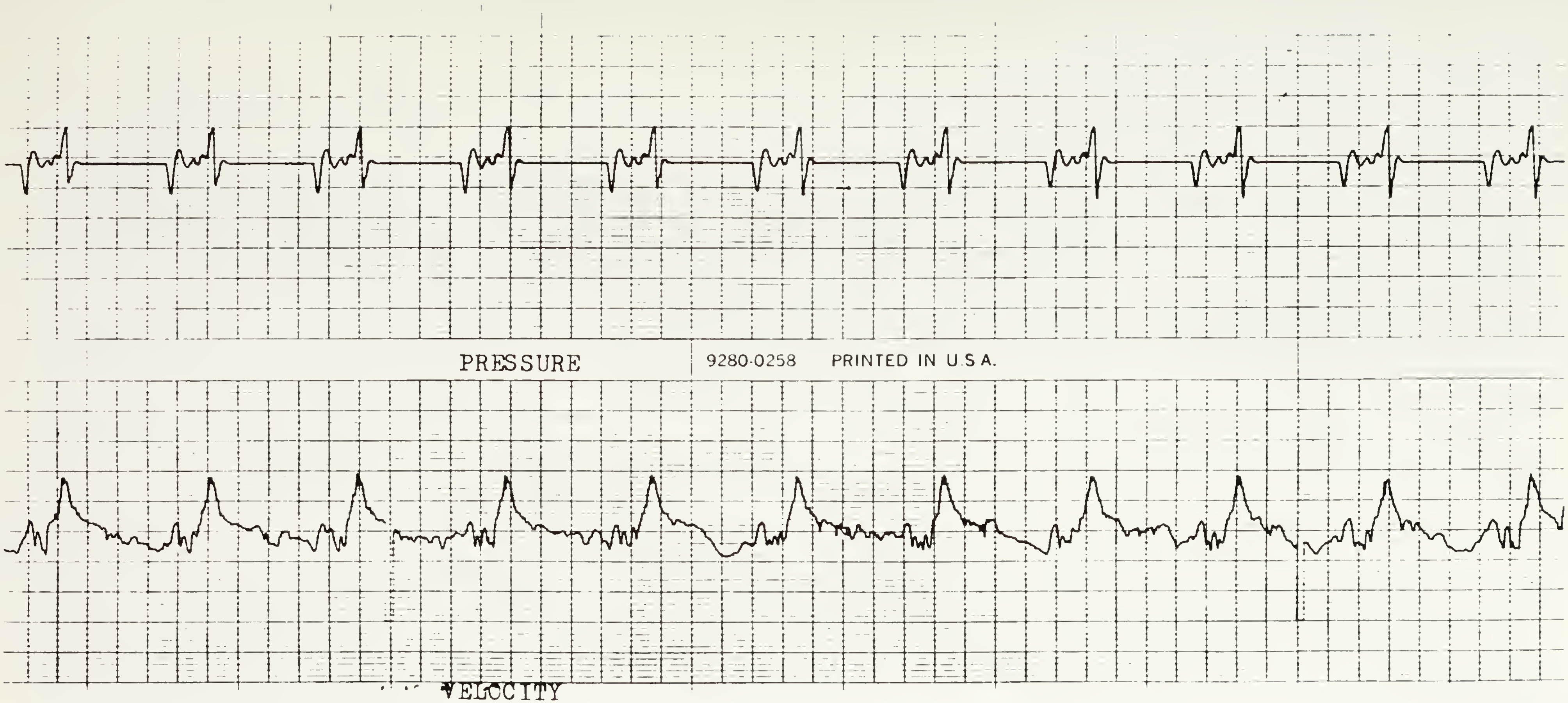
PRESSURE AND VELOCITY RECORD EXPERIMENT 1

FIGURE 5A



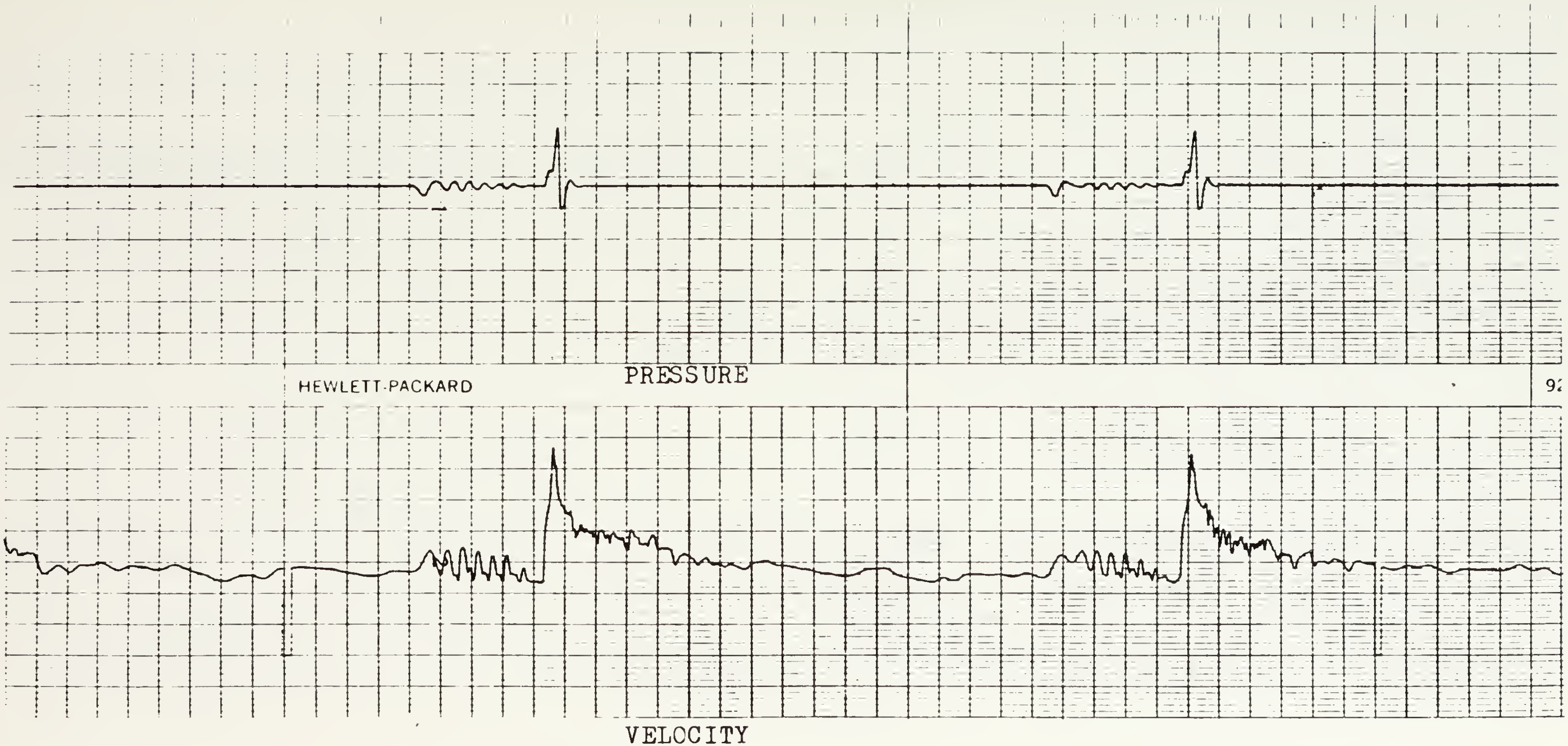
PRESSURE AND VELOCITY RECORD EXPERIMENT 2

FIGURE 5B



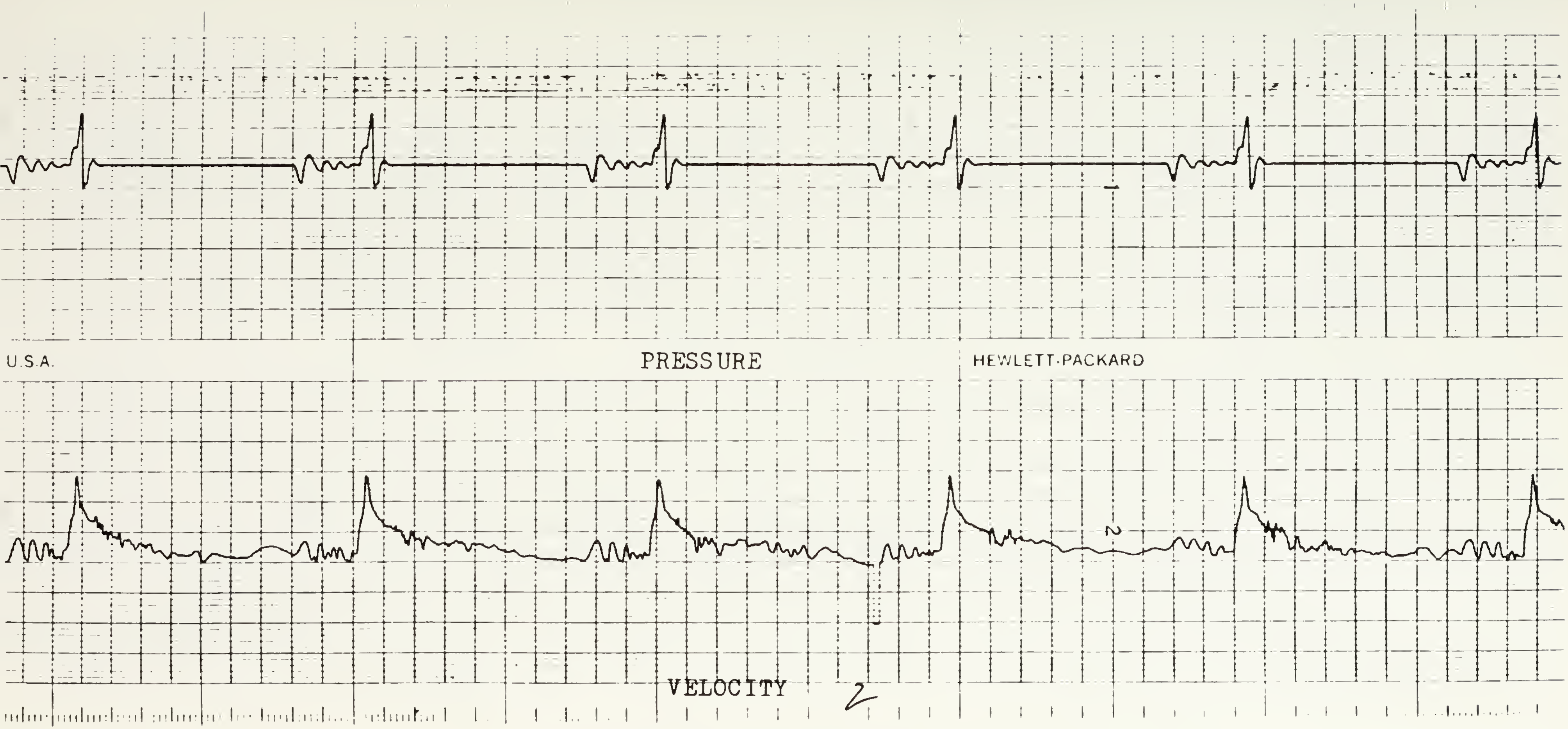
PRESSURE AND VELOCITY RECORD EXPERIMENT 3

FIGURE 5C



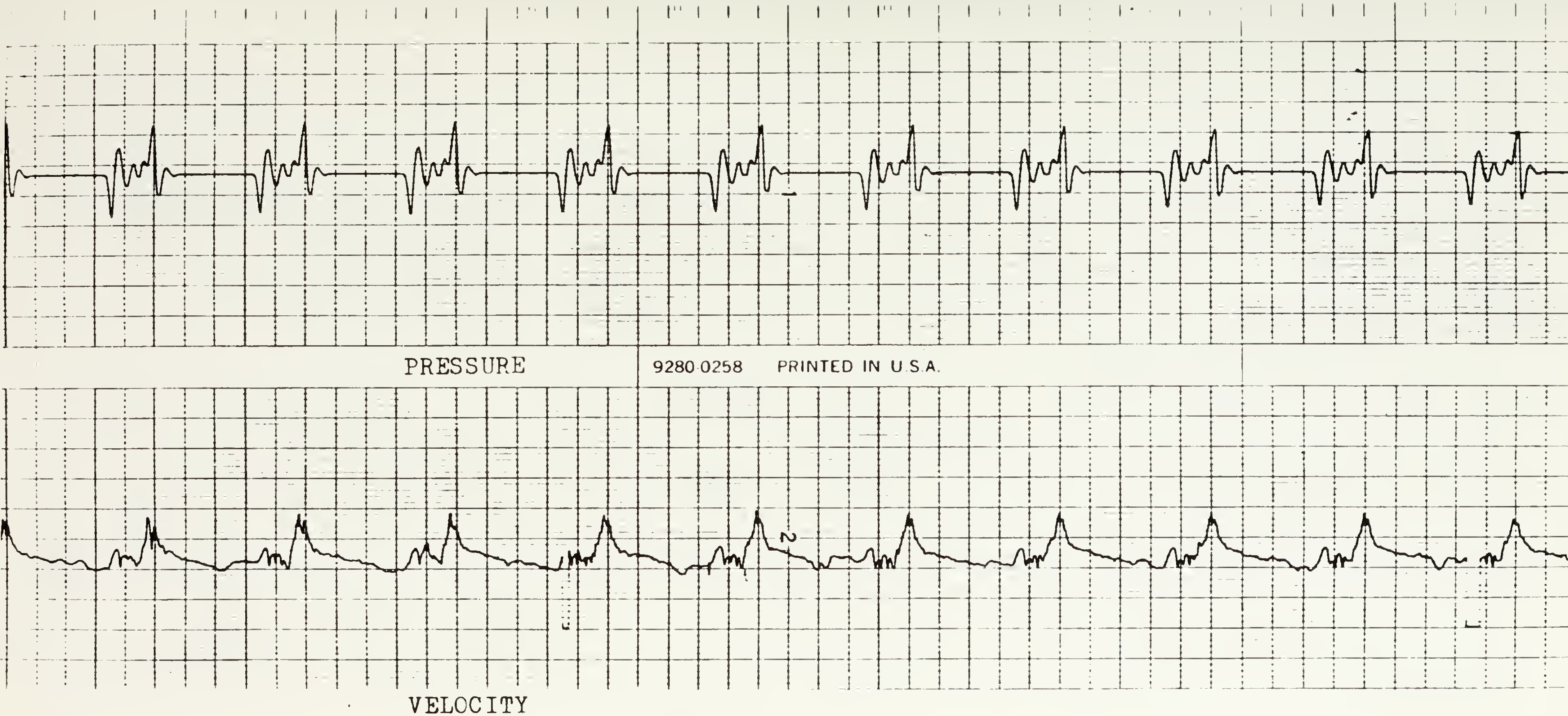
PRESSURE AND VELOCITY RECORD EXPERIMENT 4

FIGURE 5D



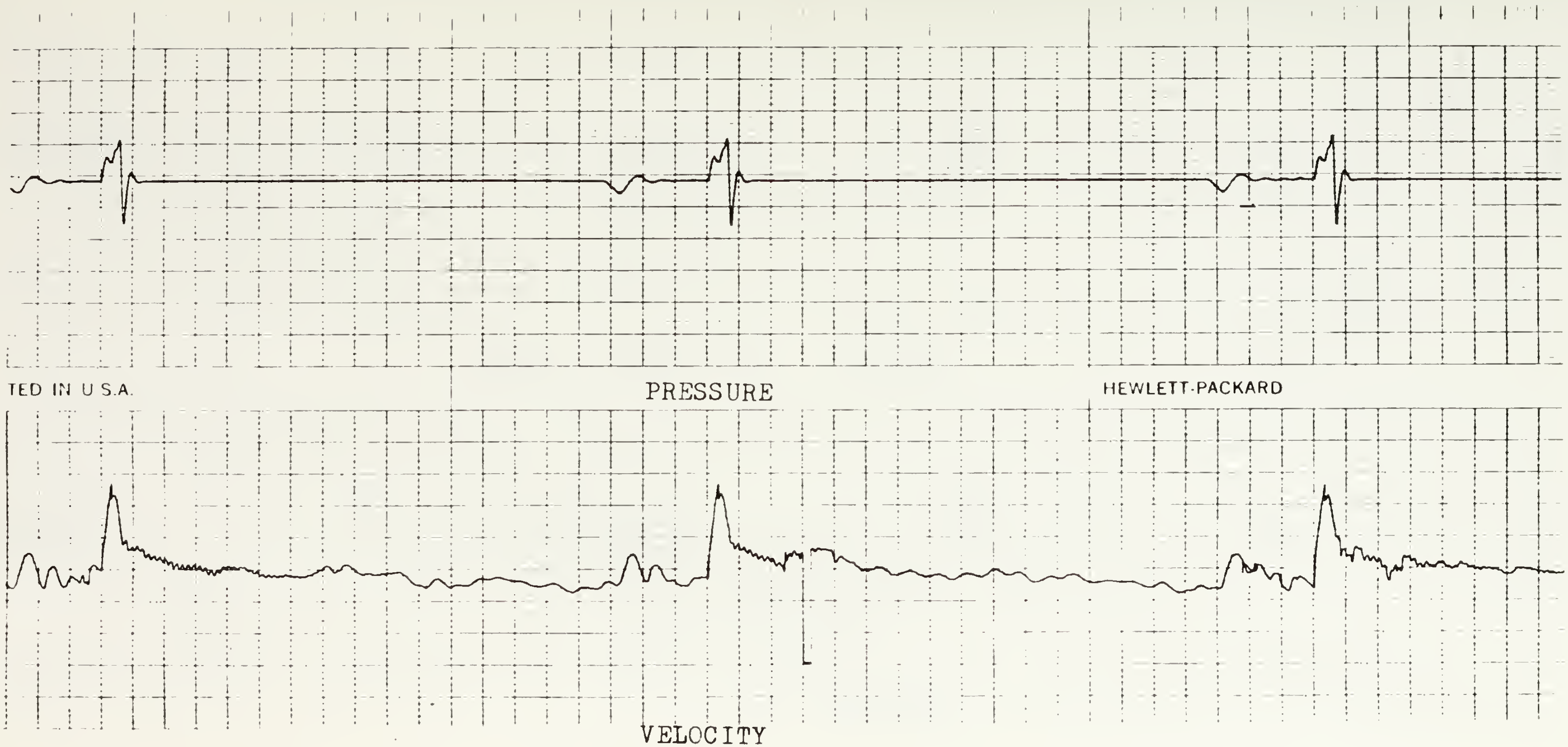
PRESSURE AND VELOCITY RECORD EXPERIMENT 5

FIGURE 5E



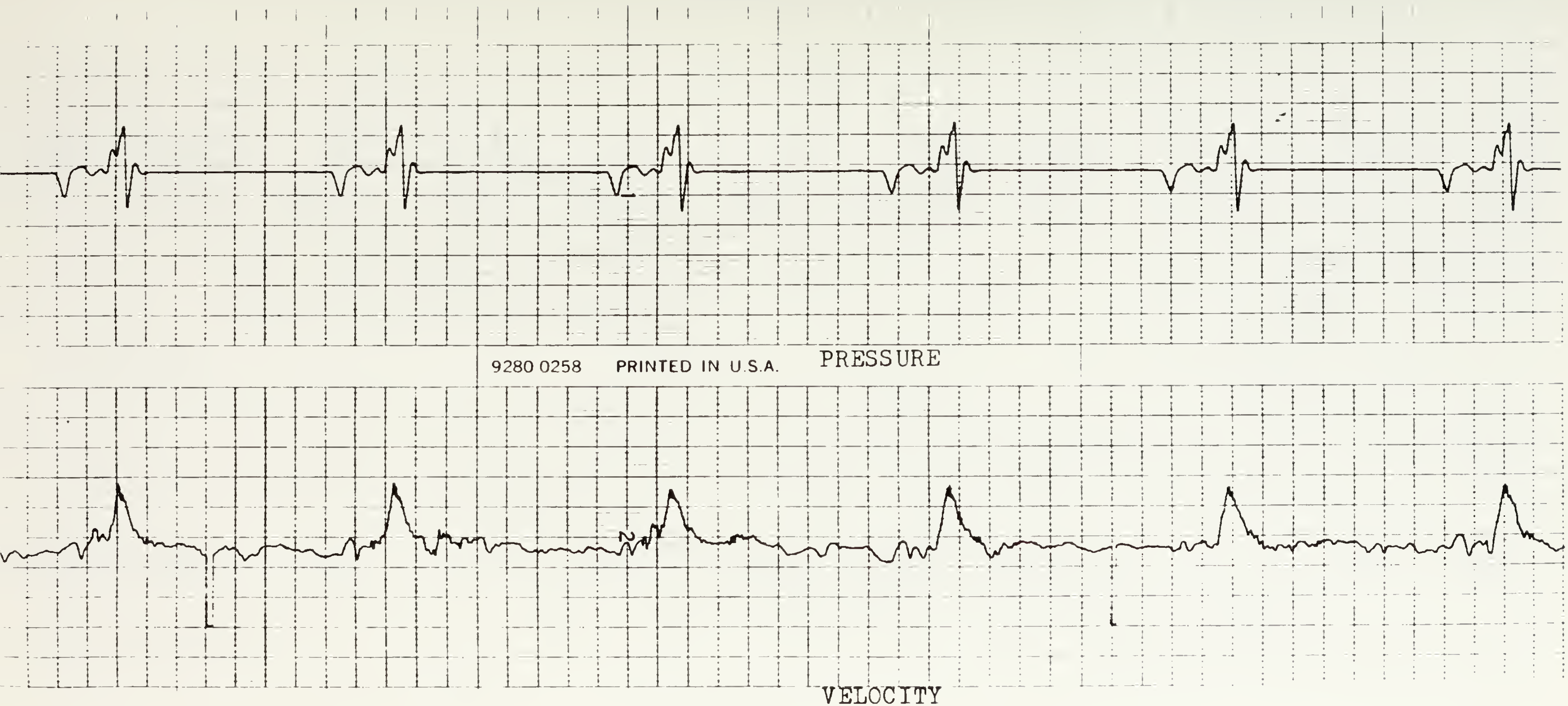
PRESSURE AND VELOCITY RECORD EXPERIMENT 6

FIGURE 5F



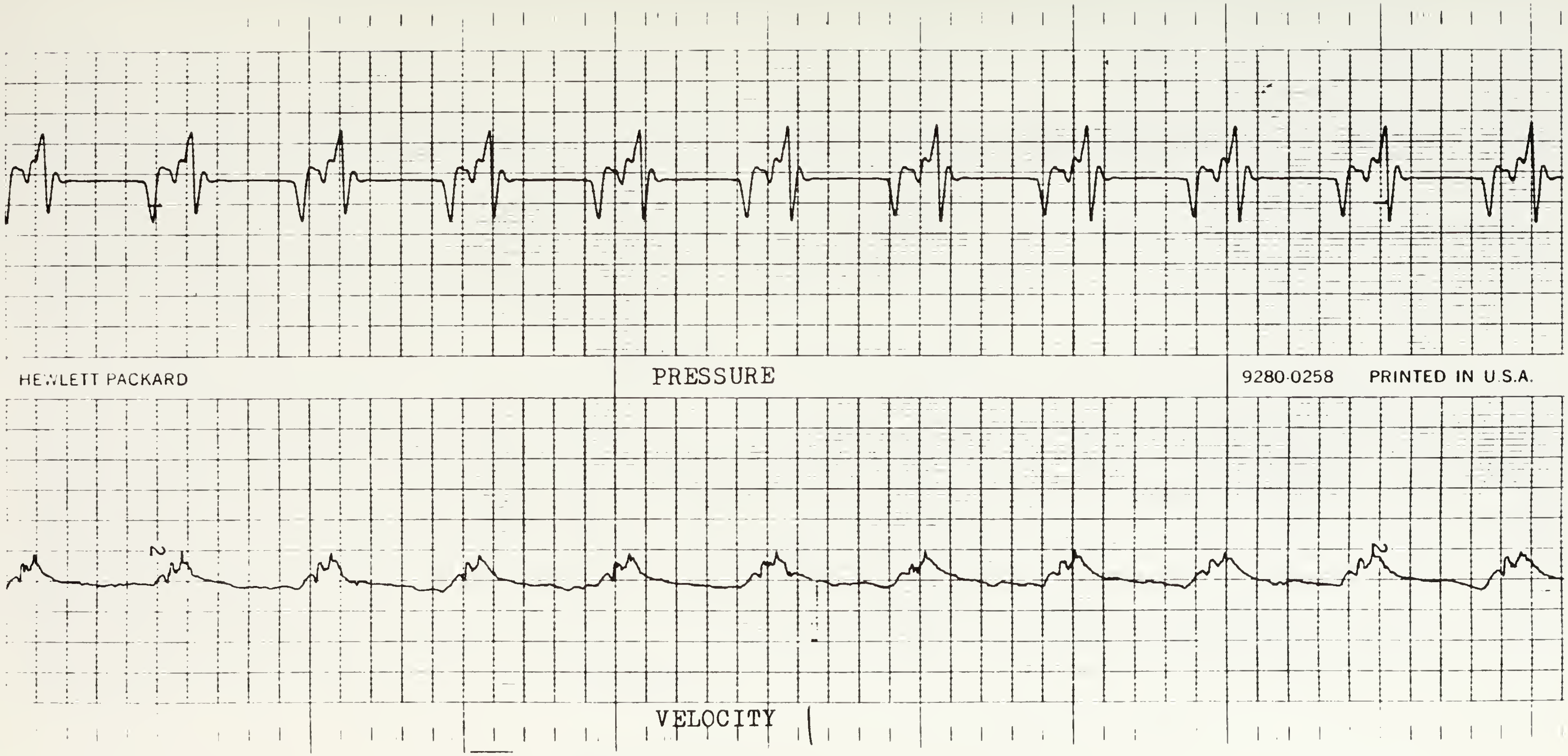
PRESSURE AND VELOCITY RECORD EXPERIMENT 7

FIGURE 5 G



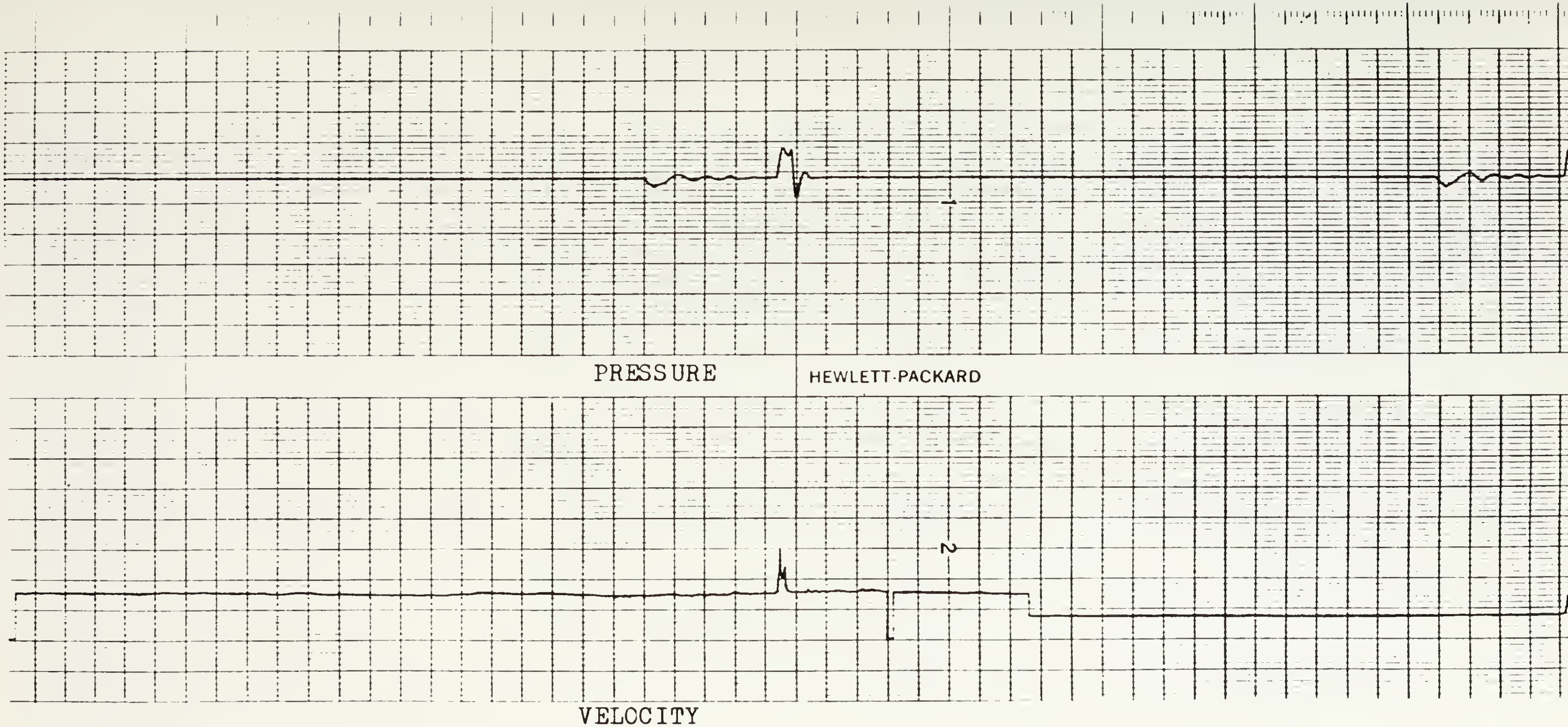
PRESSURE AND VELOCITY RECORD EXPERIMENT 8

FIGURE 5 H



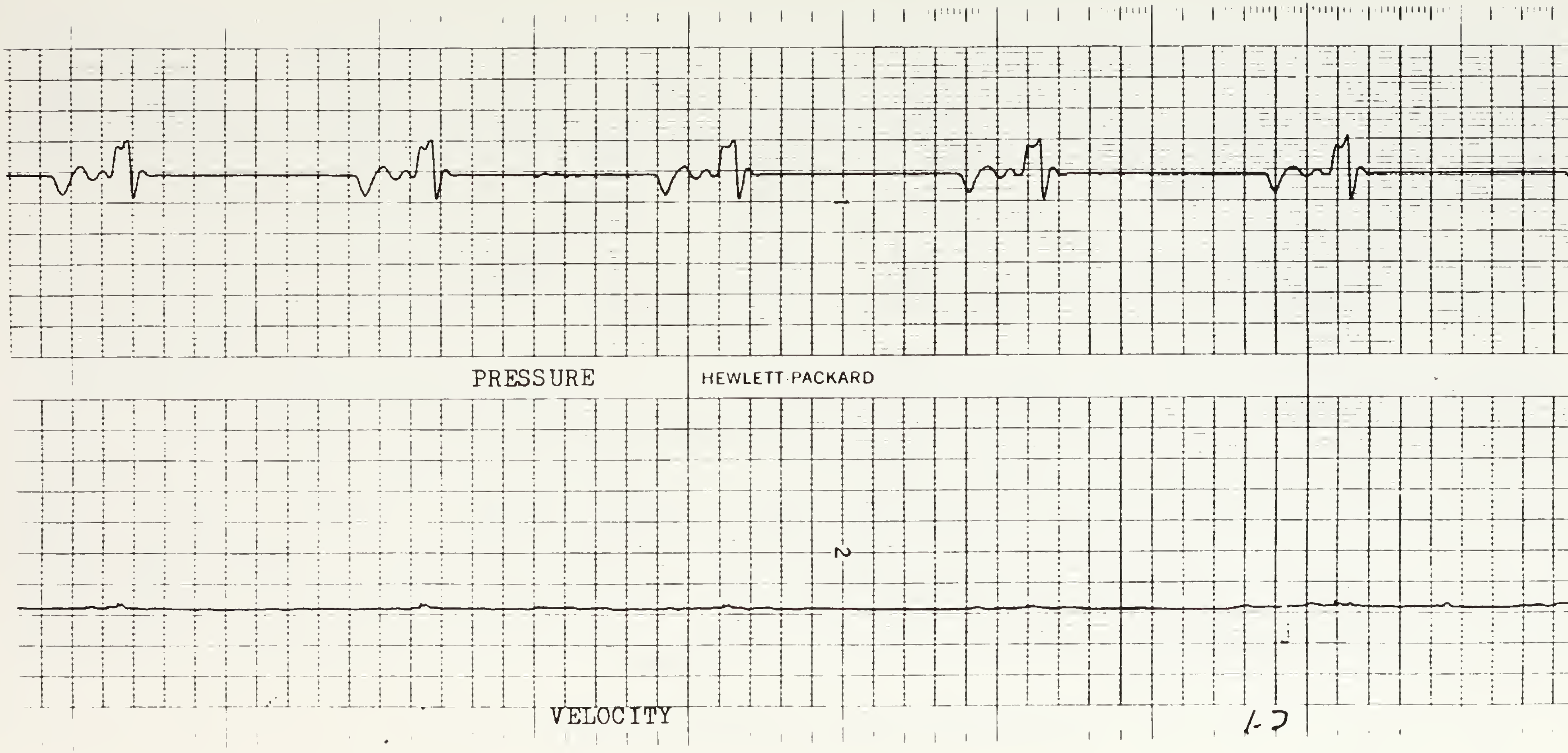
PRESSURE AND VELOCITY RECORD EXPERIMENT 9

FIGURE 5-I



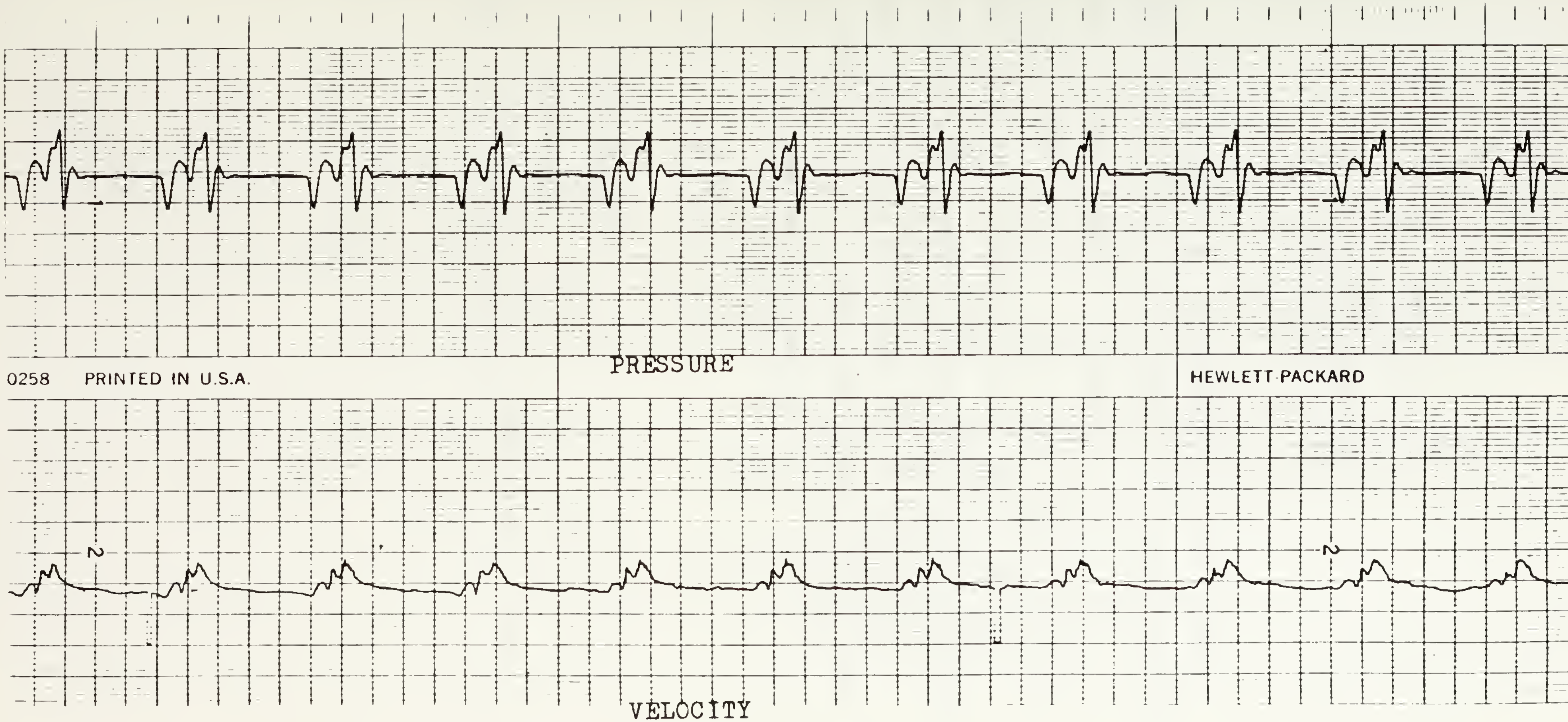
PRESSURE AND VELOCITY RECORD EXPERIMENT 10

FIGURE 5 J



PRESSURE AND VELOCITY RECORD EXPERIMENT 11

FIGURE 5 K



PRESSURE AND VELOCITY RECORD EXPERIMENT 12

FIGURE 5 L

CHAPTER V

DISCUSSION OF RESULTS

As one reviews the results depicted by the figures (Appendix A), certain trends appear. The first observation is that the experiments that produce the most rapid subsidence have the larger plate areas, greater weights, larger amplitudes of oscillation, and shorter periods. Secondly, the experiments that subside more rapidly also had higher negative pore water pressures and thus higher liquefaction indexes as derived by Sleath (12), where the point of fluidization is regarded as :

$$\frac{1}{\rho g}\frac{\delta p}{\delta y} \qquad \frac{\rho_{1} - \rho}{\rho}$$

ρ = water density

ρ_{1} = bed density

$\frac{\delta p}{\delta y}$ = pore-water pressure through the transducer depth dy

Failure of the bed could also result from too large a horizontal gradient :

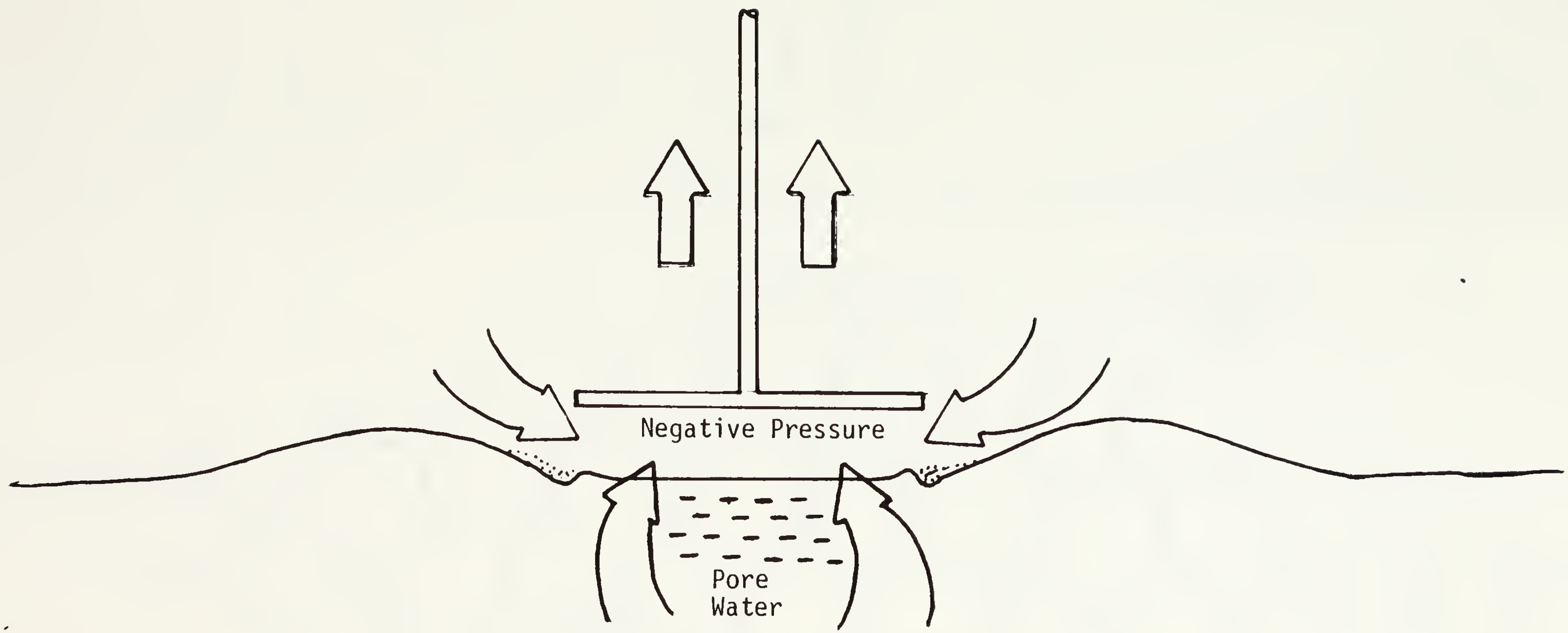
$$\frac{1}{\rho g} \frac{\delta p}{\delta y} = \frac{\rho_1 - \rho}{\rho} \tan \theta$$

where θ = internal angle of friction

As the plate is uplifted, as depicted in Figure 6, negative pore water pressures are developed locally in the foundation soil directly under the plate. The data indicate that the bed is indeed fluidized. Assuming that the pore-water pressure is incompressible and that the grain skeleton is compressible and deformable, the action of local fluidization of the bed would than cause distortion of the upper grain layers (see Figure 7).

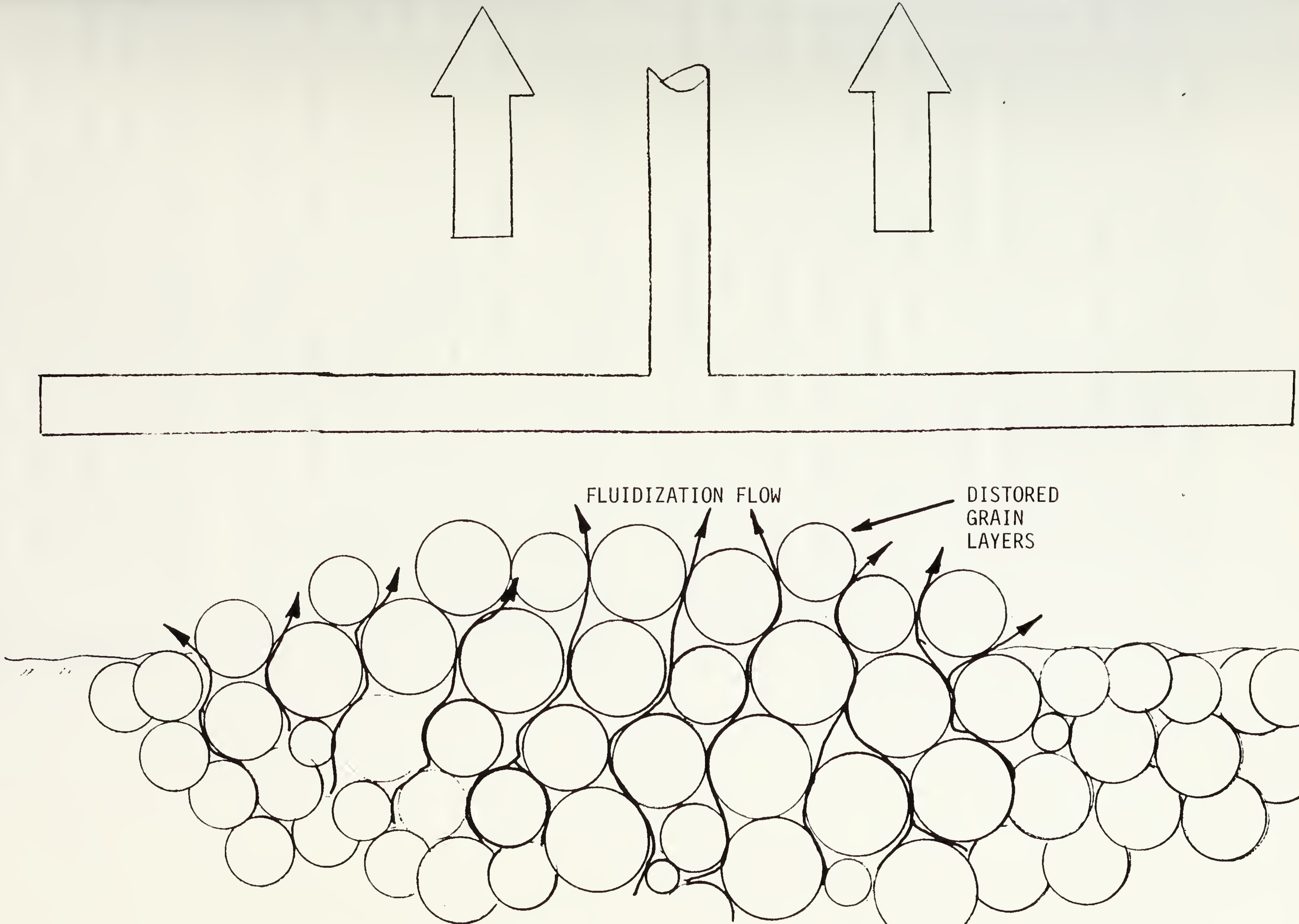
Some of the loose grains were observed to be carried into suspension by the turbulent flow of fluid rushing in under the plate in response to the local negative pressures. The strip chart record reflects the velocity response to the pressure fluctuations which are in agreement with the Bernoulli equation :

$$p = -\tfrac{1}{2} \rho V2 - gx + C$$



UPWARD PLATE CYCLE

FIGURE 6

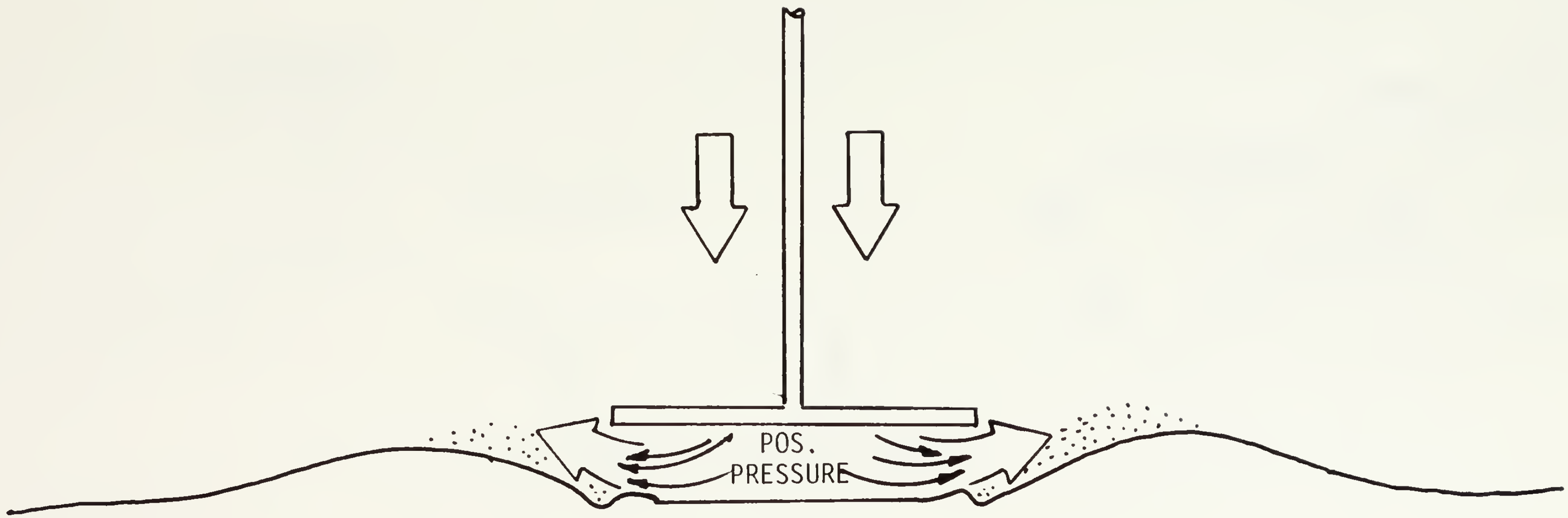


Distorted Grain Skeleton
FIGURE 7

During the downward cycle of the plate (Figure 8), the loosened grains as well as the sediment in suspension (as a result of the uplifting of the plate) can then be easily transported (Figure 8) at a much lower shear velocities (u*) then would be required for normal initiation as predicted by the Shields' diagram (6). An interesting observation, derived from the pressure and velocity records, is that the slower periods have more pressure fluctuations and thus more velocity fluctuations but with lower negative pore water pressures than do the shorter period cycles which have greater negative pore water pressures but with a faster change in pressure and velocity with fewer fluctuations.

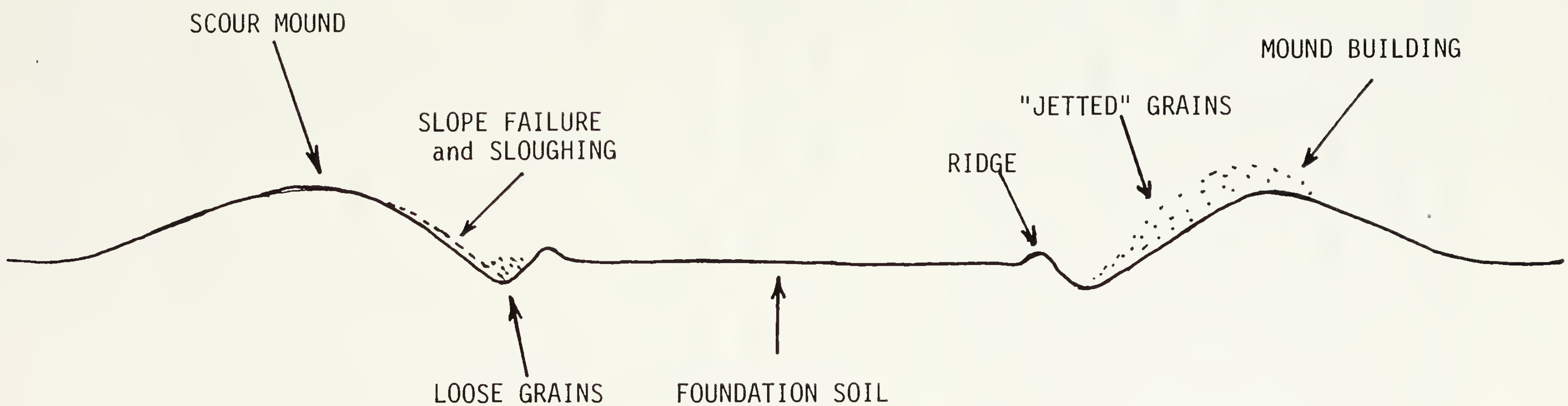
By careful observation three interesting details were discovered. First, a small ridge of sand developed along and under the perimeter edge of the plate. The second observation is that a trough was developed immediately adjacent to the perimeter edge of the plate (Figure 9). Thirdly, slope instability and sloughing was observed during the upstroke of the plate. These seemingly minor details may play a significant role in the pumping erosion process.

The small ridge under the perimeter of the plate probably results from the outflow of water and transported material attempting to exit from the underside of the plate during the last fraction of a second before plate impact. This small ridge of sand may account for the large negative



DOWNWARD PLATE CYCLE

FIGURE 8



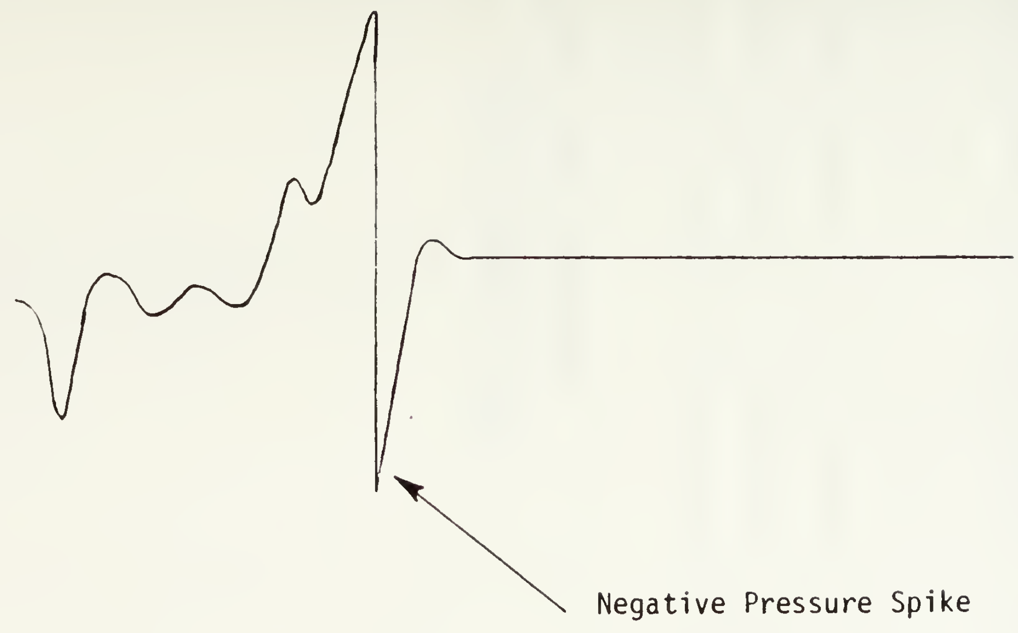
BED PROFILE DETAILS

FIGURE 9

pore water spikes at the end of each cycle (Figure 10) in one of two ways. First, if the foundation bed is considered to be elastic, the negative pore water pressure may be due to plate-soil bounce with the small ridge acting to seal the plate so that the pressure response is localized. The second possibility, is that as the plate impacts on the foundation soil, the plate undergoes slight flexure and causes the negative pressure excursion. Again, the sand ridge would tend to seal off the plate to cause the event to be a local effect.

The trough is caused by the jetting of water from under the plate (Figure 9). During the uplifting of the plate, the lower portion of the slope became unstable and sloughed onto the aforementioned trough. The entire slope then cascaded down to form a new equilibrium slope. The slope failure was probably due to the pressure/velocity field near the edge of the plate. As the water rushes in, responding to the negative pressures under the plate, sand grains at the base of the slope could be enveloped by the turbulent flow causing a slope failure. An alternate explanation, is that there is flow out of the slope in response to the pressure fluctuation, which would also cause the slope failure.

TYPICAL PORE-WATER PRESSURE RECORD



NEGATIVE PORE-WATER PRESSURE SPIKE

FIGURE 10

In any event, the sand from the slope failure, which should be large grains due to preferential transportation (winnowing), loosely fall into the trough only to be expelled and transported during the downward stroke of the plate.

Topographical plots of the sand contours for the 12 experiments are in Appendix C. Of particular interest is the dynamic angle of repose of the scour mound slopes as listed in Table 2.

TABLE 2 DYNAMIC ANGLES OF REPOSE

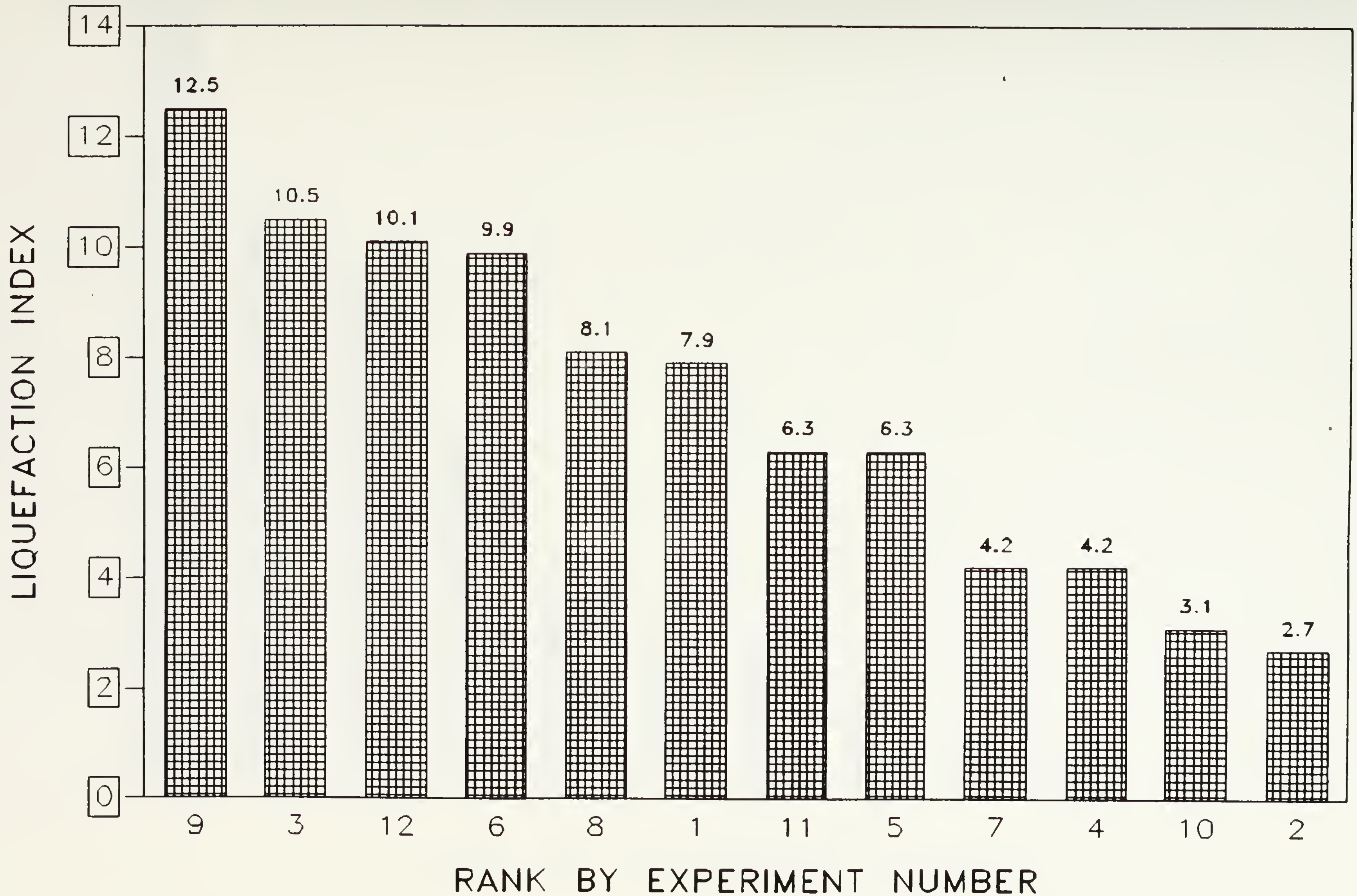
EXP. NO.	DYNAMIC ANGLE OF REPOSE
1	21
2	24.3
3	24.9
4	24.2
5	23.4
6	25.8
7	23.3
8	22.2
9	23.8
10	22.2
11	22.4
12	22.7

Figure 11, ranks the experiments by the average initial liquefaction index. The ranking is in accordance with the observed subsidence rates (i.e. the tests with more rapid subsidence have higher liquefaction indexes). A relationship between the period, amplitude, plate weight and plate area (A2Ap/WT2) was then developed and ranked (Figure 12). Curiously enough, the ranking was the same as the liquefaction index except for the positions of experiments 2 and 4, which were reversed.

Although some general trends were developed from the plotted data and figures, a more sophisticated numerical analysis is required to ascertain the relationships between the experimental parameters.

MULTIVARIATE PROCEDURES

To determine the relationship and relative importance of the variables the Statistical Analysis System, or SAS, was employed. The SAS techniques were used to analyze the data because of the statistical integrity and ease of use. All of the statistical methods employed are explained in the SAS User's Manual : Statistics (11). The data from all 12 experiments were compiled into 234 observations, using 15 variables. The dependent variable was subsidence (SUBSID). The 14 independent variables were : period (T), amplitude of oscillation (A), plate area (AP), plate weight (W), plate thickness (TH), bed density (BRHO), kinematic viscosity



LIQUEFACTION INDEX
14
12
10
8
6
4
2
0
12.5
10.5
10.1
9.9
8.1
7.9
6.3
6.3
4.2
4.2
3.1
2.7
9
3
12
6
8
1
11
5
7
4
10
2
RANK BY EXPERIMENT NUMBER

FIGURE 11

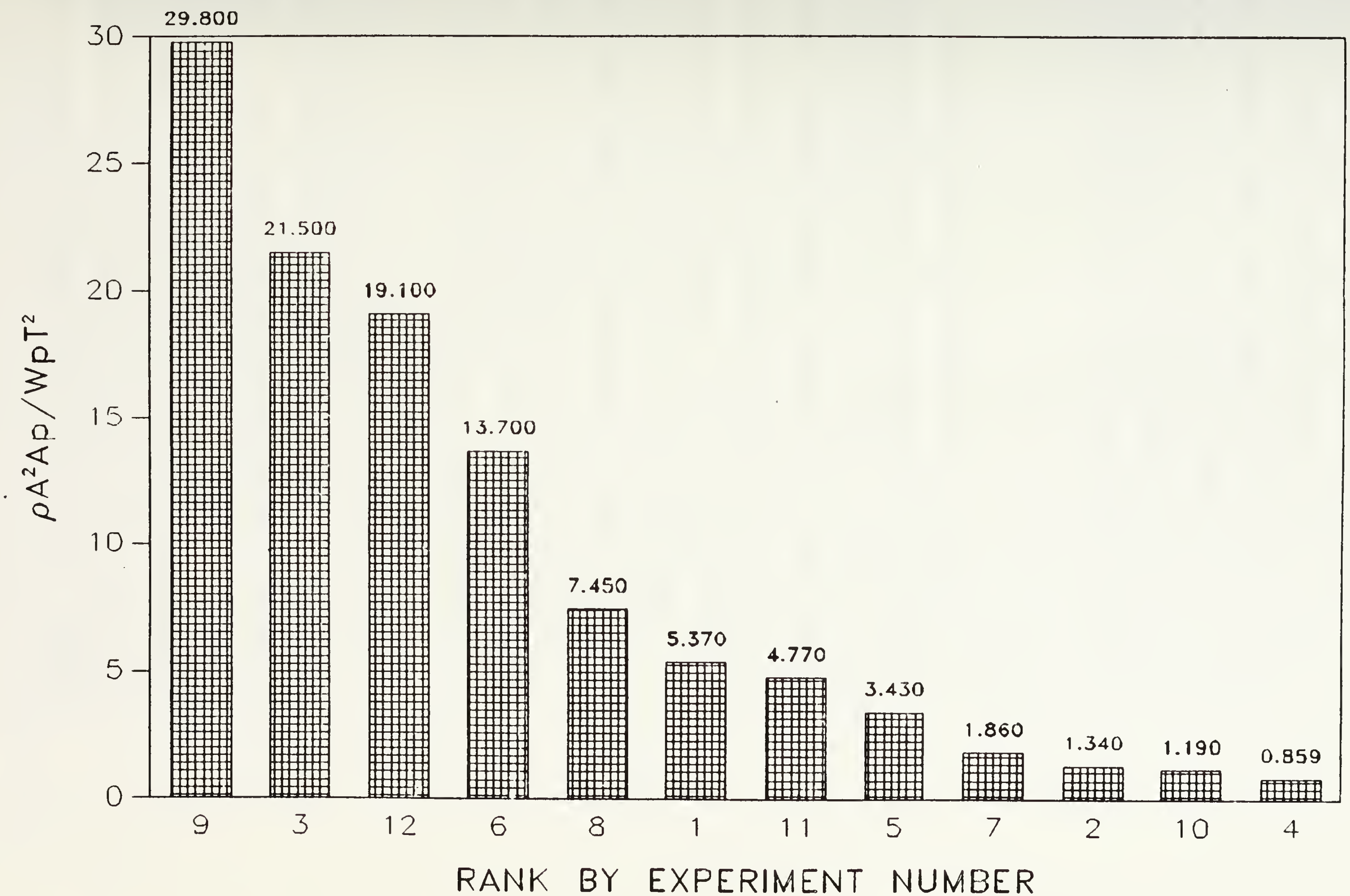

29.800
21.500
19.100
13.700
7.450
5.370
4.770
3.430
1.860
1.340
1.190
0.859
30
25
20
15
10
5
0
$\rho A^2 A p / W p T^2$
9
3
12
6
8
1
11
5
7
2
10
4
RANK BY EXPERIMENT NUMBER

FIGURE 12

(VISC), number of cycles (CYCS), negative pore water pressures (PPWS), liquefaction index (LI), positive pore-water pressures (PPWP), plate upward velocity (VPU), plate downward velocity (VPD) and plate exit velocity (VE). Table 3 summarizes the range of values for each of the variables. A list of all the variable values can be found in Appendix B.

The SAS procedure, PROC CORR, was first used to determine simple linear correlations between the variables in the entire data record and are listed in Table 4. Due to the high correlation between the area of the plate (AP) and the plate weight (W) and plate thickness (TH), W and TH were deleted form further analysis. Also LI was deleted from analysis due to the high cross correlation with PPWS. Furthermore, PPWP was not considered for further analysis because of its low correlation (-0.016) with subsidence. This is an interesting event as data suggests that positive pore-water pressures have little to do with subsidence.

The next step was to determine the strength of the linear relationship determined by computing R2 , the square of the multiple correlation coefficient (R-SQUARE in SAS). R2 also known as the coefficient of determination, is interpreted as the portion of the variability that has been accounted for by the regression formula. The closer R2 was to 1, the better the model equation fit the data. However,

					MINIMUM	MAXIMUM
SUBSID	234	0.87252137	0.49662039	204.17000000	0.00000000	1.80000000
T	234	12.60683761	6.42214151	2950.00000000	5.00000000	20.00000000
A	234	0.90598291	0.10003484	212.00000000	0.80000000	1.00000000
AP	234	1.55555556	0.49796917	364.00000000	1.00000000	2.00000000
W	234	31.11111111	5.47766088	7280.00000000	25.00000000	36.00000000
TH	234	0.02279060	0.01508186	5.33300000	0.01100000	0.04200000
BRHO	234	3.30000000	0.00000000	772.20000000	3.30000000	3.30000000
VISC	234	8.643632479E-06	2.564751859E-07	0.00202261	8.572000000E-06	9.558000000E-06
CYCS	234	57.70512821	61.83645722	13503.00000000	0.00000000	330.00000000
PPWS	234	-0.05997062	0.03383271	-14.03312500	-0.15050000	0.00000000
LI	234	5.82564440	3.28504000	1363.20078877	0.00000000	14.62002150
PPWP	234	0.13190342	0.04737528	30.86540000	0.00000000	0.27950000
VPU	234	1.23989104	0.77448035	290.13450288	0.00000000	3.31250000
VPD	234	3.45703568	1.27409096	808.94634921	0.00000000	6.62500000

TABLE 3

	SUBSID	T	A	AP	W	TH	BRHD	VISC	CYCS	PPWS	LI	PPWP	VPU
SUBSID	1.00000 0.0000	-0.14989 0.0218	0.33653 0.0001	-0.12561 0.0550	-0.12561 0.0550	0.17205 0.0084	0.00000 1.0000	0.16004 0.0142	0.78867 0.0001	-0.26279 0.0001	0.26263 0.0001	-0.01559 0.8125	0.33956 0.0001
T	-0.14989 0.0218	1.00000 0.0000	-0.09787 0.1355	0.14911 0.0225	0.14911 0.0225	0.00411 0.9501	0.00000 1.0000	-0.11386 0.0822	-0.10256 0.1177	0.75520 0.0001	-0.75479 0.0001	-0.14508 0.0265	-0.44255 0.0001
A	0.33653 0.0001	-0.09787 0.1355	1.00000 0.0000	-0.03255 0.6203	-0.03255 0.6203	0.17351 0.0078	0.00000 1.0000	0.26362 0.0001	0.25034 0.0001	-0.13645 0.0370	0.13843 0.0343	-0.05586 0.3950	-0.08521 0.1940
AP	-0.12561 0.0550	0.14911 0.0225	-0.03255 0.6203	1.00000 0.0000	1.00000 0.0001	-0.87592 0.0001	0.00000 1.0000	-0.31293 0.0001	-0.34269 0.0001	0.20161 0.0019	-0.20266 0.0018	0.08661 0.1867	0.38359 0.0001
W	-0.12561 0.0550	0.14911 0.0225	-0.03255 0.6203	1.00000 0.0001	1.00000 0.0000	-0.87592 0.0001	0.00000 1.0000	-0.31293 0.0001	-0.34269 0.0001	0.20161 0.0019	-0.20266 0.0018	0.08661 0.1867	0.38359 0.0001
TH	0.17205 0.0084	0.00411 0.9501	0.17351 0.0078	-0.87592 0.0001	-0.87592 0.0001	1.00000 0.0000	0.00000 1.0000	0.35726 0.0001	0.35013 0.0001	-0.09894 0.1313	0.09998 0.1272	-0.07254 0.2691	-0.36328 0.0001
BRHD	0.00000 1.0000	0.00000 1.0000	0.00000 1.0000	0.00000 1.0000	0.00000 1.0000	0.00000 1.0000	0.00000 1.0000	0.00000 1.0000	0.00000 1.0000	0.00000 1.0000	0.00000 1.0000	0.00000 1.0000	0.00000 1.0000
VISC	0.16004 0.0142	-0.11386 0.0822	0.26362 0.0001	-0.31293 0.0001	-0.31293 0.0001	0.35726 0.0001	0.00000 1.0000	1.00000 0.0000	0.06324 0.3354	-0.13192 0.0438	0.13385 0.0408	0.23366 0.0003	-0.15482 0.0178
CYCS	0.78867 0.0001	-0.10256 0.1177	0.25034 0.0001	-0.34269 0.0001	-0.34269 0.0001	0.35013 0.0001	0.00000 1.0000	0.06324 0.3354	1.00000 0.0000	-0.18109 0.0055	0.18093 0.0055	-0.25706 0.0001	0.19966 0.0021
PPWS	-0.26279 0.0001	0.75520 0.0001	-0.13645 0.0370	0.20161 0.0019	0.20161 0.0019	-0.09894 0.1313	0.00000 1.0000	-0.13192 0.0438	-0.18109 0.0055	1.00000 0.0000	-0.99989 0.0001	-0.46163 0.0001	-0.55476 0.0001
LI	0.26263 0.0001	-0.75479 0.0001	0.13843 0.0343	-0.20266 0.0018	-0.20266 0.0018	0.09998 0.1272	0.00000 1.0000	0.13385 0.0408	0.18093 0.0055	-0.99989 0.0001	1.00000 0.0000	0.46212 0.0001	0.55323 0.0001
PPWP	-0.01559 0.8125	-0.14508 0.0265	-0.05586 0.3950	0.08661 0.1867	0.08661 0.1867	-0.07254 0.2691	0.00000 1.0000	0.23366 0.0003	-0.25706 0.0001	-0.46163 0.0001	0.46212 0.0001	1.00000 0.0000	0.24294 0.0002
VPU	0.33956 0.0001	-0.44255 0.0001	-0.08521 0.1940	0.38359 0.0001	0.38359 0.0001	-0.36328 0.0001	0.00000 1.0000	-0.15482 0.0178	0.19966 0.0021	-0.55476 0.0001	0.55323 0.0001	0.24294 0.0002	1.00000 0.0000
VPD	0.63126 0.0001	-0.04687 0.4755	0.21594 0.0009	0.15387 0.0185	0.15387 0.0185	-0.09608 0.1428	0.00000 1.0000	0.06520 0.3207	0.34825 0.0001	-0.35979 0.0001	0.36016 0.0001	0.40962 0.0001	0.44448 0.0001

	VPD
SUBSID	0.63126 0.0001
T	-0.04687 0.4755
A	0.21594 0.0009

TABLE 4

	VPD
AP	0.15387 0.0185
W	0.15387 0.0185
TH	-0.09608 0.1428
BRHO	0.00000 1.0000
VISC	0.06520 0.3207
CYCS	0.34825 0.0001
PPWS	-0.35979 0.0001
LI	0.36016 0.0001
PPWP	0.40962 0.0001
VPU	0.44448 0.0001
VPD	1.00000 0.0000

TABLE 4 (cont.)

a large R2 did not necessarily mean that the proper model was chosen for the data. Therefore, R2 should be used with caution, since it is always possible to make R2 large by the addition of more variables to the model. The R-SQUARE routine was configured to give R2 and C(p) values for all possible combinations of 3, 4 and 5 variables. The results are listed in Appendix D. C(p), Mallow's statistic, is a criteron related to the mean square of a fitted value (7). As C(p) attempts to indicates the bias of the prediction, a small C(p) value is generally sought. The "best fit" model is determined by when C(p) first approaches p on a plot of C(p) versus p.

Next, the remaining 10 variables were incorporated into a SAS routine called STEPWISE. STEPWISE is a model building program which chooses variables that are to be included into the model. Ideally, a variable selection process should provide for any given number of independent variables, a subset whose equation of predicted values produce the minimal residual sum of the squares. In PROC STEPWISE variables are added or deleted one at a time, depending on the Forward or Backward option selection, until all coefficients remaining in the model are statistically significant ($P < 0.0001$).

The STEPWISE procedure, using the backward elimination method, gave results that are suspect. It indicated that the best model was produced when all the variables were significant at the $P < 0.001$ level when the variable AP (plate area) was removed. This result is contradictory to the forward selection process which adds variables in the order of there significance. The forward selection process ranked the variables in order of significance in the following manner:

TABLE 5 FORWARD SELECTION RANKING

Variables	C(p)	F	PROB>F	R2
CYCS	185.049	381.754	0.0001	0.6220
VPD	28.146	143.304	0.0001	0.7667
VISC	20.663	8.842	0.0033	0.7754
AP	16.634	5.737	0.0174	0.7808
T	14.272	4.209	0.0414	0.7848
PPWS	11.090	5.091	0.0250	0.7895
A	9.307	3.761	0.0537	0.7930
VPU	9.000	2.307	0.1302	0.7951

The significance of the ranking is apparent in the manner in which the forward selection was constructed, in that it added the variables in the following order : CYCS, VPD, VISC, AP, T, PPWS, A and VPU. Each additional variable improved the overall fit of the model.

The strength of a linear relationship, an indication of how well the model fits the data, is indicated by the R2 value. The F-value is used by SAS to test the null hypothesis, which tests the linear association between Y and X1, X2, ... Xk . If the F-value is not significant (PROB F = 0.0001), for a system on "n" degrees of freedom (DF), the null hypothesis is accepted indicating that the model does not explain a significant portion of the variability. That is to say, as the F-value increases a greater portion of the variability is explained by the model (i.e. the spread of the model is lessened).

The PROB >F indicates the significance of the model (or the strength of the variables as in the R2 output). The lower the value of PROB>F , the more significant the model . A p-value of 0.0001 is highly significant.

The strength of the individual variables in indicated by, T and PROB>T, which denote the same inference as F and PROB>F.

Based on the above results, PROC REG was performed on the 8 remaining independent variables. Variables A (amplitude) and VPU (plate upward velocity) were then removed and PROC REG was run again. The results are shown in Tables 6 and 7.

Two variables, F1 and F2 were then created from the combination of the 8 variables where :

$$F1 = \{(144\ PPWS\ VPU\ AP/(\ g2T))\}1/3$$

$$F2 = \{(1/2VPD2\ A\ W\ )/(144\ VISC2\ g2\ T2\ \ )\}1/2$$

F3 and F4 were created from the log of F1 and F2 taking into account the number of cycles. PROC CORR, PROC RSQUARE and PROC REG were then utilized on F1, F2 F3, and F4. The results are listed in Tables 8, 9 and 10.

Plots of the models (Figures 13, 14 & 15) listed in Tables 6, 7 and 10, graph the predicted values from the models against the actual values.

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	8	45.68964740	5.71120592	109.126	0.0001
ERROR	225	11.77556499	0.05233584		
C TOTAL	233	57.46521239			

ROOT MSE	0.2287703	R-SQUARE	0.7951
DEP MEAN	0.8725214	ADJ R-SQ	0.7878
C.V.	26.21945		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR HO: PARAMETER=0	PROB > |T|	VARIANCE INFLATION
INTERCEP	1	-1.73874055	0.57144946	-3.043	0.0026	0
T	1	-0.01095138	0.003935050	-2.783	0.0058	2.84326286
A	1	0.42042178	0.17661015	2.381	0.0181	1.38960255
AP	1	0.01313021	0.04990345	0.263	0.7927	2.74930400
CYCS	1	0.005016776	0.000330433	15.182	0.0001	1.85871204
PPWS	1	2.51070987	0.91528286	2.743	0.0066	4.26914558
VISC	1	184744.67	65070.20512	2.839	0.0049	1.23997161
VPU	1	0.05393236	0.03550625	1.519	0.1302	3.36656485
VPD	1	0.15774911	0.01602032	9.847	0.0001	1.85481184

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
1	0	0	0.3511	0.0823	0.1890	0.5132	-0.3511
2	0.3	0.3000	0.7218	0.0594	0.6048	0.8388	-0.4218
3	0.5	0.5000	0.8237	0.0585	0.7085	0.9389	-0.3237
4	0.7	0.7000	0.9916	0.0617	0.8700	1.1131	-0.2916
5	0.9	0.9000	1.0515	0.0602	0.9329	1.1700	-0.1515
6	1	1.0000	0.9851	0.0575	0.8718	1.0985	0.0149
7	1.1	1.1000	1.0489	0.0577	0.9352	1.1625	0.0511
8	1.15	1.1500	1.0097	0.0577	0.8961	1.1233	0.1403
9	1.2	1.2000	1.0507	0.0572	0.9381	1.1634	0.1493
10	1.3	1.3000	1.0886	0.0561	0.9781	1.1991	0.2114
11	1.45	1.4500	1.1895	0.0560	1.0792	1.2997	0.2605
12	1.5	1.5000	1.2638	0.0561	1.1533	1.3743	0.2362
13	1.6	1.6000	1.4106	0.0570	1.2982	1.5230	0.1894
14	1.65	1.6500	1.5451	0.0589	1.4292	1.6611	0.1049
15	1.75	1.7500	1.6938	0.0614	1.5728	1.8147	0.0562
16	1.75	1.7500	1.6874	0.0652	1.5590	1.8158	0.0626
17	1.8	1.8000	1.7372	0.0825	1.5746	1.8997	0.0628

TABLE 6

DEP VARIABLE: SUBSID

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	6	45.37093938	7.56182323	141.929	0.0001
ERROR	227	12.09427301	0.05327874		
C TOTAL	233	57.46521239			

ROOT MSE	0.2308219	R-SQUARE	0.7895
DEP MEAN	0.8725214	ADJ R-SQ	0.7840
C.V.	26.45458		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR HO: PARAMETER=0	PROB > |T|	VARIANCE INFLATION
INTERCEP	1	-1.72105573	0.57516987	-2.992	0.0031	0
T	1	-0.01198702	0.003929845	-3.050	0.0026	2.78556077
AP	1	0.07103360	0.03798907	1.870	0.0628	1.56503552
CYCS	1	0.005357586	0.000293743	18.239	0.0001	1.44286802
PPWS	1	1.85197583	0.82078459	2.256	0.0250	3.37236072
VISC	1	216545.59	63172.91467	3.428	0.0007	1.14803346
VPD	1	0.16325034	0.01596531	10.225	0.0001	1.80949475

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
1	0	0	0.2999	0.0795	0.1432	0.4565	-0.2999
2	0.3	0.3000	0.7033	0.0594	0.5863	0.8203	-0.4033
3	0.5	0.5000	0.8171	0.0589	0.7010	0.9331	-0.3171
4	0.7	0.7000	0.9706	0.0614	0.8497	1.0916	-0.2706
5	0.9	0.9000	1.0446	0.0606	0.9251	1.1641	-0.1446
6	1	1.0000	0.9742	0.0578	0.8602	1.0882	0.0258
7	1.1	1.1000	1.0390	0.0580	0.9247	1.1534	0.0610
8	1.15	1.1500	0.9904	0.0573	0.8775	1.1032	0.1596
9	1.2	1.2000	1.0361	0.0572	0.9235	1.1488	0.1639
10	1.3	1.3000	1.0878	0.0566	0.9763	1.1993	0.2122
11	1.45	1.4500	1.1929	0.0564	1.0817	1.3041	0.2571
12	1.5	1.5000	1.2708	0.0565	1.1596	1.3821	0.2292
13	1.6	1.6000	1.4266	0.0571	1.3141	1.5391	0.1734
14	1.65	1.6500	1.5688	0.0584	1.4537	1.6839	0.0812
15	1.75	1.7500	1.7246	0.0604	1.6057	1.8435	0.0254
16	1.75	1.7500	1.7059	0.0653	1.5772	1.8346	0.0441
17	1.8	1.8000	1.7972	0.0777	1.6441	1.9503	.0027678
18	0	0	-0.0335	0.0490	-0.1301	0.0630	0.0335
19	0.4	0.4000	0.3438	0.0365	0.2720	0.4157	0.0562

TABLE 7

SUBSID	234	0.87252137	0.49662039	204.17000000	0.00000000	1.80000000
F1	234	0.07749584	0.04442540	18.13402693	0.00000000	0.20648259
F2	234	306.56648784	246.26760224	71736.55815530	0.00000000	1321.26788358
F3	234	0.39936874	0.55385457	93.45228467	-1.31685812	1.52242192
F4	234	3.76186847	1.07561958	880.27722131	0.00000000	5.19850802

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER HO:RHO=0 / N = 234

	SUBSID	F1	F2	F3	F4
SUBSID	1.00000	0.30010	0.34619	0.83789	0.78081
	0.0000	0.0001	0.0001	0.0001	0.0001
F1	0.30010	1.00000	0.90915	0.52540	0.61492
	0.0001	0.0000	0.0001	0.0001	0.0001
F2	0.34619	0.90915	1.00000	0.52613	0.56979
	0.0001	0.0001	0.0000	0.0001	0.0001
F3	0.83789	0.52540	0.52613	1.00000	0.69315
	0.0001	0.0001	0.0001	0.0000	0.0001
F4	0.78081	0.61492	0.56979	0.69315	1.00000
	0.0001	0.0001	0.0001	0.0001	0.0000

TABLE 8 A

N=234 REGRESSION MODELS FOR DEPENDENT VARIABLE: SUBSID MODEL: MODEL1

NUMBER IN MODEL	R-SQUARE	C(P)	VARIABLES IN MODEL
1	0.09006019	1500.011	F1
1	0.11984469	1443.383	F2
1	0.60967168	512.106	F4
1	0.70205439	336.465	F3
2	0.12107963	1443.036	F1 F2
2	0.62410039	486.674	F2 F4
2	0.66179646	415.005	F1 F4
2	0.71444217	314.913	F2 F3
2	0.72917656	286.899	F1 F3
2	0.77907053	192.039	F3 F4

TABLE 8 B

DEP VARIABLE: SUBSID

ANALYSIS OF VARIANCE

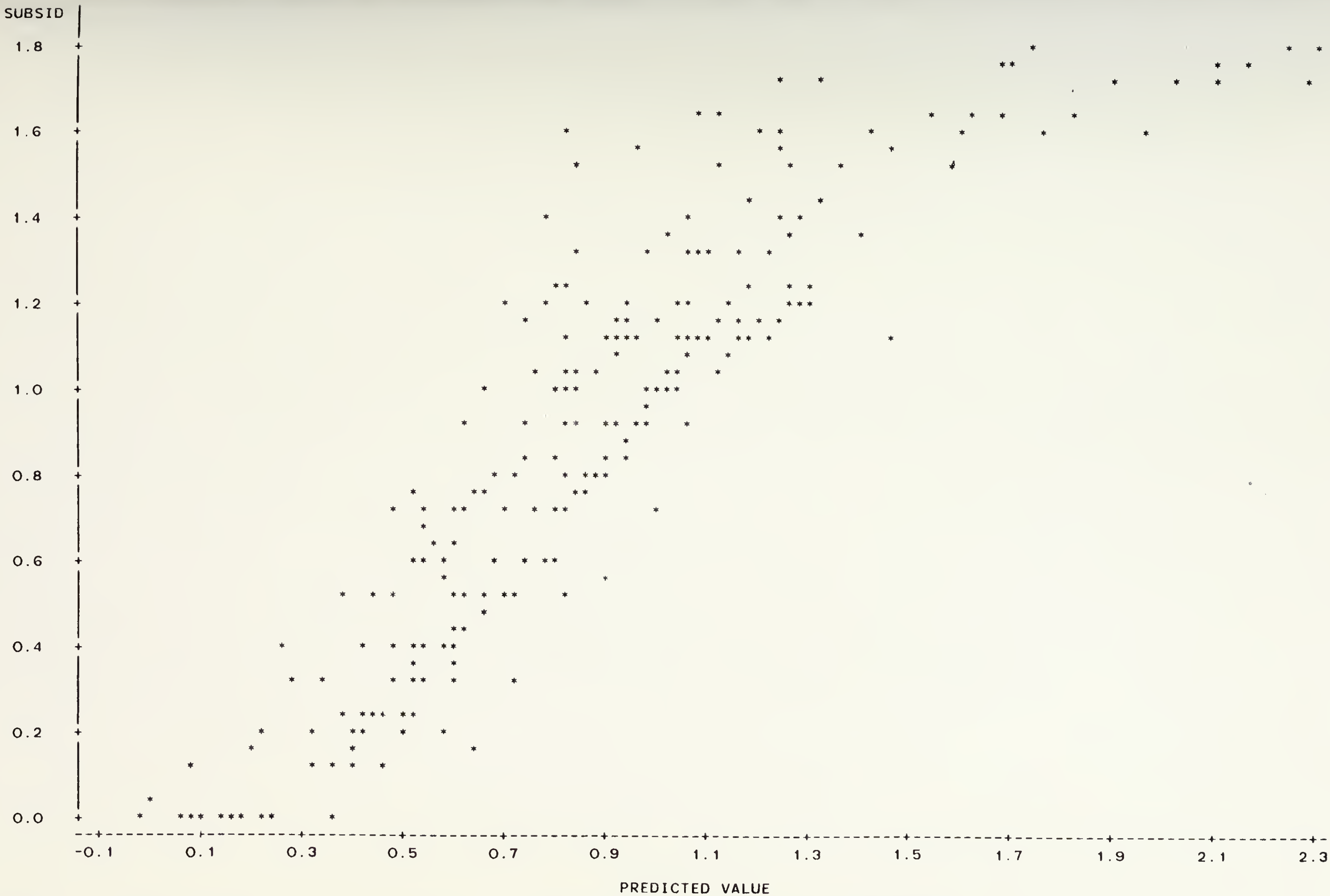
SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	38.03027386	19.01513693	226.010	0.0001
ERROR	231	19.43493854	0.08413393		
C TOTAL	233	57.46521239			

ROOT MSE	0.2900585	R-SQUARE	0.6618
DEP MEAN	0.8725214	ADJ R-SQ	0.6589
C.V.	33.24371		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR HO: PARAMETER=0	PROB > |T|
INTERCEP	1	-0.54206629	0.06980071	-7.766	0.0001
F1	1	-3.23642674	0.54240887	-5.967	0.0001
F4	1	0.44270481	0.02240265	19.761	0.0001

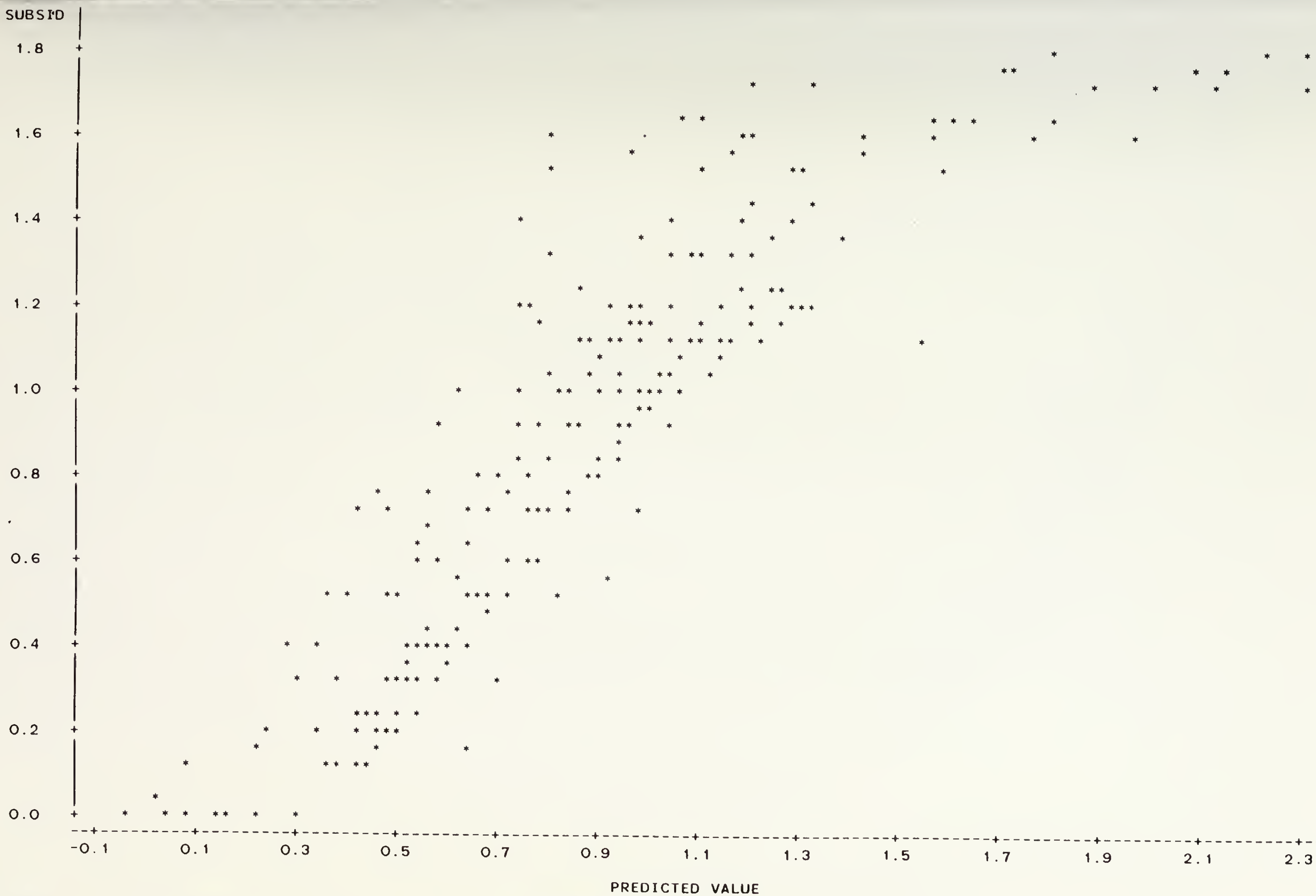
OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
1	0	0	-0.5421	0.0698	-0.6796	-0.4045	0.5421
2	0	0	-0.5421	0.0698	-0.6796	-0.4045	0.5421
3	0	0	-0.5421	0.0698	-0.6796	-0.4045	0.5421
4	0	0	-0.5421	0.0698	-0.6796	-0.4045	0.5421
5	0	0	-0.5421	0.0698	-0.6796	-0.4045	0.5421
6	0	0	-0.5421	0.0698	-0.6796	-0.4045	0.5421
7	0	0	-0.5421	0.0698	-0.6796	-0.4045	0.5421
8	0	0	-0.5421	0.0698	-0.6796	-0.4045	0.5421
9	0	0	-0.5421	0.0698	-0.6796	-0.4045	0.5421
10	0	0	-0.5421	0.0698	-0.6796	-0.4045	0.5421
11	0	0	-0.5421	0.0698	-0.6796	-0.4045	0.5421
12	0	0	-0.5421	0.0698	-0.6796	-0.4045	0.5421
13	0.05	0.0500	0.0155	0.0448	-0.0728	0.1038	0.0345
14	0.1	0.1000	0.2431	0.0365	0.1711	0.3151	-0.1431
15	0.1	0.1000	0.2614	0.0345	0.1935	0.3294	-0.1614
16	0.1	0.1000	0.3813	0.0361	0.3101	0.4524	-0.2813
17	0.12	0.1200	0.4458	0.0279	0.3908	0.5008	-0.3258
18	0.12	0.1200	0.3522	0.0317	0.2897	0.4148	-0.2322
19	0.12	0.1200	0.4142	0.0289	0.3572	0.4712	-0.2942
20	0.15	0.1500	0.4200	0.0313	0.3584	0.4817	-0.2700
21	0.15	0.1500	0.5334	0.0268	0.4805	0.5863	-0.3834



NOTE: 24 OBS HIDDEN

PREDICTED VS ACTUAL- 8 variable model

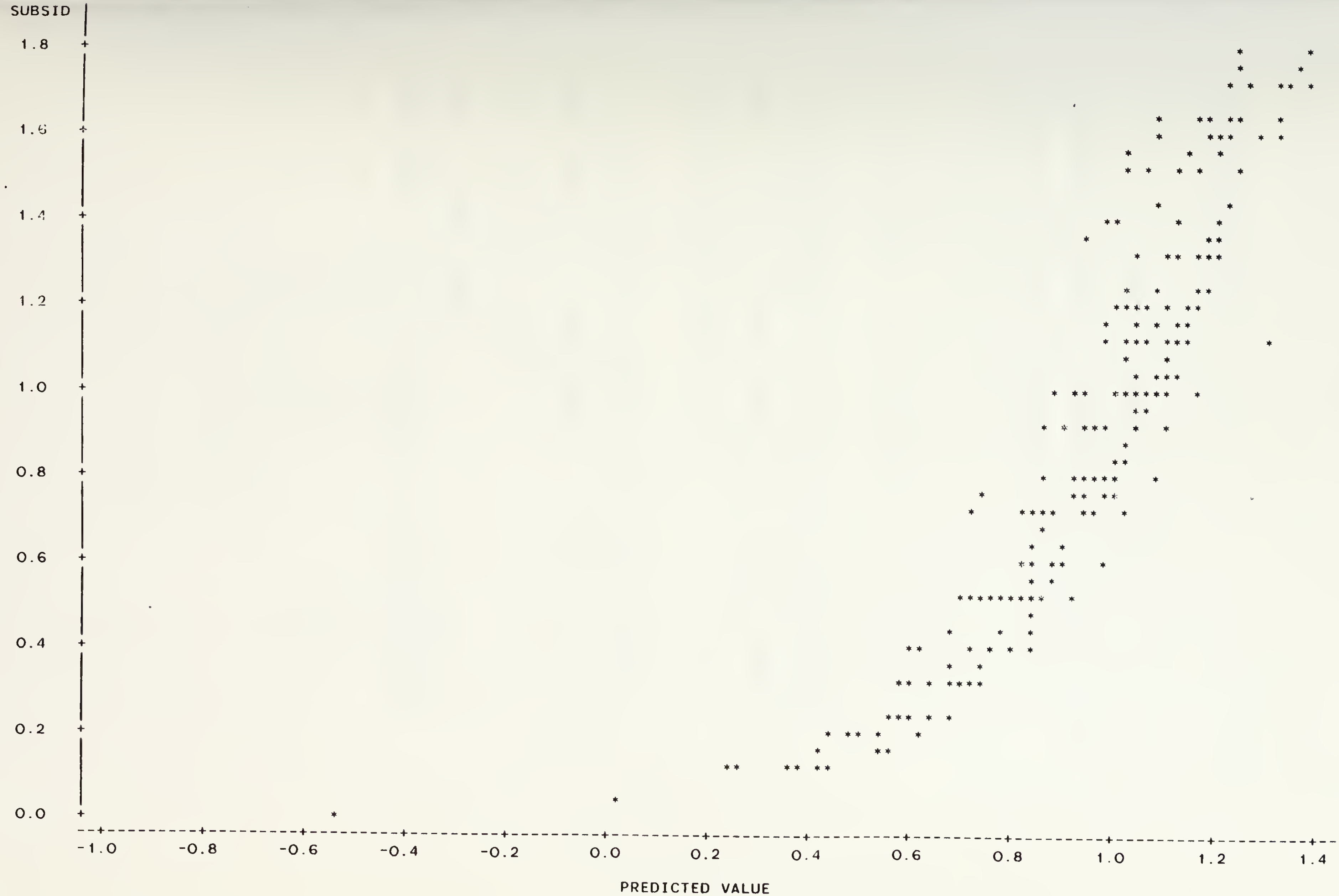
FIGURE 13



NOTE: 32 OBS HIDDEN

PREDICTED VS ACTUAL - 6 variable model

FIGURE 14



NOTE: 58 OBS HIDDEN

PREDICTED VS ACTUAL - 2 term model
FIGURE 15

Multivariate Results

The SAS multiple regression was used to determine if the dependent variable Y (subsidence) was linearly related to two or more of the independent variables X1, X2,...Xk . The solution takes the form of :

$$Y = a + b1X1 + b2X2 + \ldots + bkXk$$

where "a" denotes the intercept term when X's equal zero. b1, b2,...bk are the partial regression coefficients of X1, X2,...Xk , respectively.

Below is listed a summary of MOD1, the 8 variable model; MOD2, the 6 variable model; and MOD3, the 2 variable model containing F1 and F4.

TABLE 9 MODEL SUMMARY

MOD	# VARS	R2	F-VALUE	SUM OF SQ. RESIDUALS
1	8	0.7951	109	11.78
2	6	0.7895	142	12.09
3	2*	0.6618	226	19.43

* 2 terms containing 8 variables

From Table 11, the 6 variable model was selected as the best model where:

$$Y = -1.72105 - 0.11987\ T + 0.7103\ AP + 0.00536\ CYCS + 1.85197\ PPWS + 21645.59\ VISC + 0.16325\ VPD$$

The determination of the "best" linear model is not as important to this research as is the significance of the variables. From Tables 5 and 7, it can be seen that the two most significant variables are the number of cycles (CYCS) ($F = 381.754$, $T = 18.39$, p-value = 0.0001) and downward plate velocity (VPD) ($F = 143.304$, $T = 10.225$, p-value =0.0001). The remaining variables listed in their order of significance are : viscosity (VISC), plate area (AP), Negative pore water pressure (PPWS) and period (T).

CHAPTER VI

SUMMARY AND CONCLUSIONS

The main objective of this research was to determine which mechanisms were involved in the phenomenon of pumping-erosion. The secondary objectives, involved the evaluation of the relative importance of each of the 14 independent variables, and in particular, the significance of negative pore-water pressures.

Of the original 14 independent variables, 6 variables (cycles (CYCS), downward plate velocity (VPD), viscosity (VISC), plate area (AP), negative pore water pressure (PPWS), and period (T)) were considered significant in the model constructed utilizing SAS. The number of cycles (CYCS) and the downward velocity of the plate (VPD) were highly significant and is in agreement with the accepted understanding of pumping-erosion and scour.

The result of negative pore water pressure (PPWS) remaining significant throughout the analysis supports the hypothesis that negative pore water pressures are a contributing factor in pumping-erosion. This is understandable if the experimental results of the

Liquefaction Index (fluidization index) associated with the negative pore water pressures is accepted.

This leads to the conclusion that the fluidization of the foundation soil, due to the negative pore water pressures developed during the upward cycle of the plate-footing is a precursor to the scour developed during the downward cycle of of the plate-footing and significantly contributes to the overall pumping-erosion subsidence .

As with many initial investigations, this research poses more questions than it answers. Such as :

1) If negative pore-water pressures and the subsequent fluidization are significant to the phenomenon of pumping-erosion, then what is the distribution of the negative pore water pressures under the footing ?

2) What is the distribution of velocities under the plate footing ?

3) Can the footing be designed to alter the pressure and flow nets under the footing to reduce subsidence ?

4) What effect does the shape of the scour mound have on the negative pore water pressures ?

5) How would the results vary in other cohesionless and cohesive soils ?

6) What are the effects on pivotal oscillations as opposed to vertical oscillation ?

RECOMMENDATIONS

To obtain a better understanding of pumping-erosion, more research is needed in this area. If the results are valid, the effect of negative pore water pressures may affect all dynamic structure-marine soil interactions including submarine pipelines.

For purposes of further research the following recommendations are proposed :

1) Employ hydraulic or pneumatic rams to load the soil at a constant rate with a constant amplitude.

2) Develop a method to record the dynamic formation of the scour mound slope.

3) Conduct the experiments with different grain sizes of cohesionless soils.

4) Conduct the experiments with cohesive soils.

REFERENCES

1. Dahlberg, R., "Observation of Scour Around Offshore Structures," Symposium of Geotechnical Aspects of Coastal and Offshore Structures, Dec. 1981, pp. 159-172.

2. DiBiago, Elmo, "Monitoring the Foundation Performance of Offshore Gravity Based Structures," Ground Engineering, Vol. 8 Nov. 1982.

3. Herbich, J.B., Schiller, R. E., Dunlap W.A. and Watanbe, R. K., "Seafloor Scour: Design Guidlines for Ocean-Founded Structures," Marcel Dekker Inc., New York, Basel, N.Y. (1984).

4. Martin, C.S., "Effects of a Porous Sand Bed on Incipent Sediment Motion," J. Water Resources 6(4), 1970, pp. 1162-1174.

5. Martin, C.S., and Aral, M.M., "Seepage Forces on Interfacial Bed Particles," PROC. A.S.C.E. J. Hydraul. Div. 97(HY7), 1971, pp. 1081-1100.

6. Middelton, G.V. and Southard, J.B., "Mechanics of Sediment Movement," 2nd Ed., Short Course No.3, Society of Economic Paleontologists and Mineralogists (S.E.P.M.), March 1984.

7. Montgomery, D.C., and Peck, E.A., "Introduction to Linear Regression Analysis," John Wiley & Sons, New York, N.Y., 1982.

8. Newman, J.N., "Marine Hydrodynamics," MIT Press, Cambridge, MA, 1986.

9. Oldenziel, D.M. and Brink, W.E., "Influence of Suction and Blowing on Entrainment of Sand Particles," PROC A.S.C.E. J. Hydraul. Div. 100, July 1974, pp.935-950.

10. Reimnitz, E. and Kempema, E., "Dynamic Ice-Wallowing Relief of Northern Alaska's Nearshore," J. Sedimentary Petrology, Vol. 52, No.2, June 1982, pp. 451-461.

11. SAS Institute Inc., "SAS/Statistics User's Guide, 1982 Edition," Cary, N.C., SAS Institute, Inc., 1982.

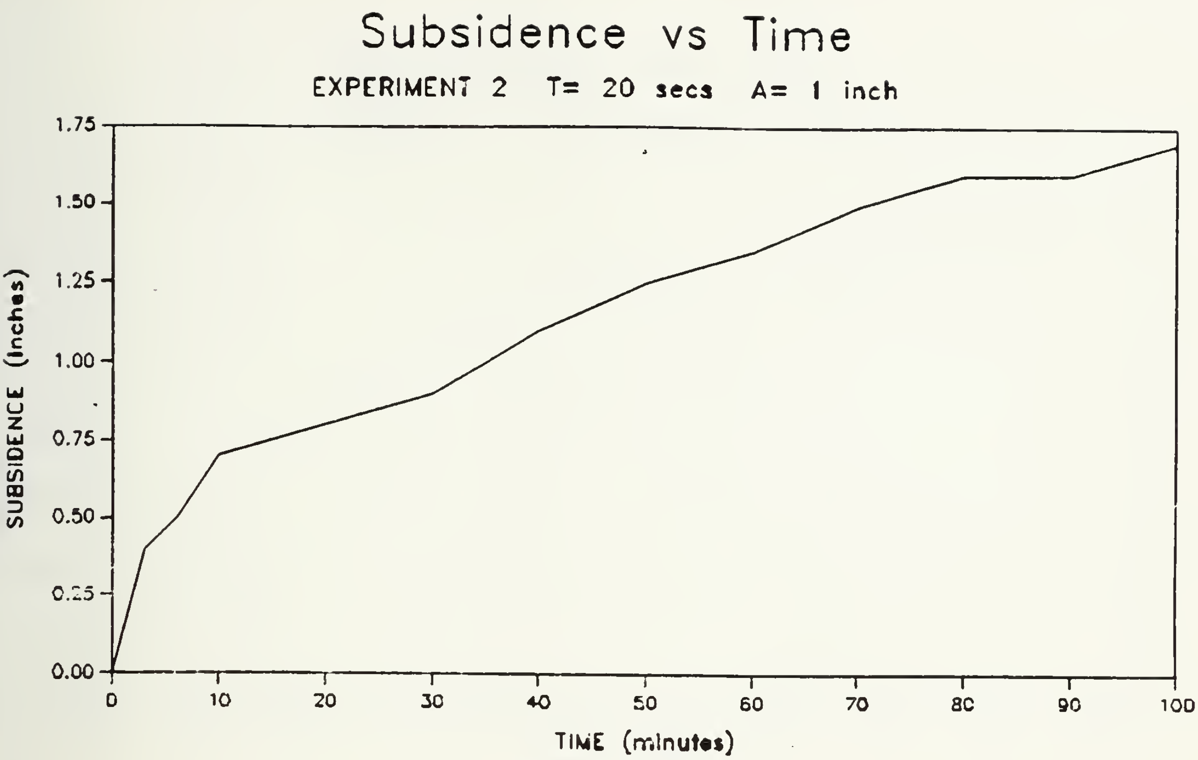
12. Sleath, J.F.A., " Sea Bed Mechanics," John Wiley & Sons, 1984, pp. 261-262.

13. Teramoto, S., Tagaya K., Murase, Y. and Nenomiya, K., "Study on Scouring of Sit-On-Bottom Type of Offshore Structures," Technical Review, Mitsubishi Heavy Industries, Vol. 10, No.1, Feb.1973, pp. 23-34.

14. Watters, G.Z. and Rao, M.V.P., "Hydrodynamic Effects of Seepage on Bed Particles," PROC A.S.C.E., J. Hydraul. Div.97 (HY3), March 1971, pp.421-439.

APPENDIX A

SUBSIDENCE CURVES


Subsidence vs Time
EXPERIMENT 2 T= 20 secs A= 1 inch
SUBSIDENCE (inches)
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
10
20
30
40
50
60
70
80
90
100
TIME (minutes)

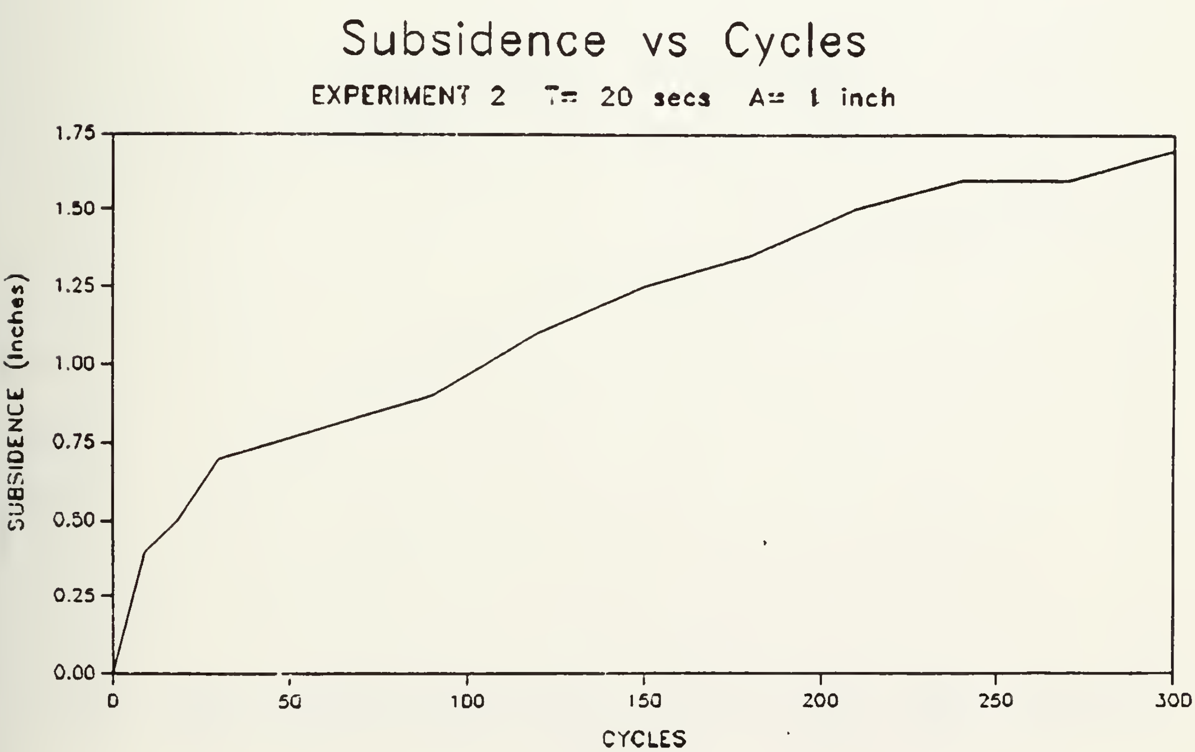
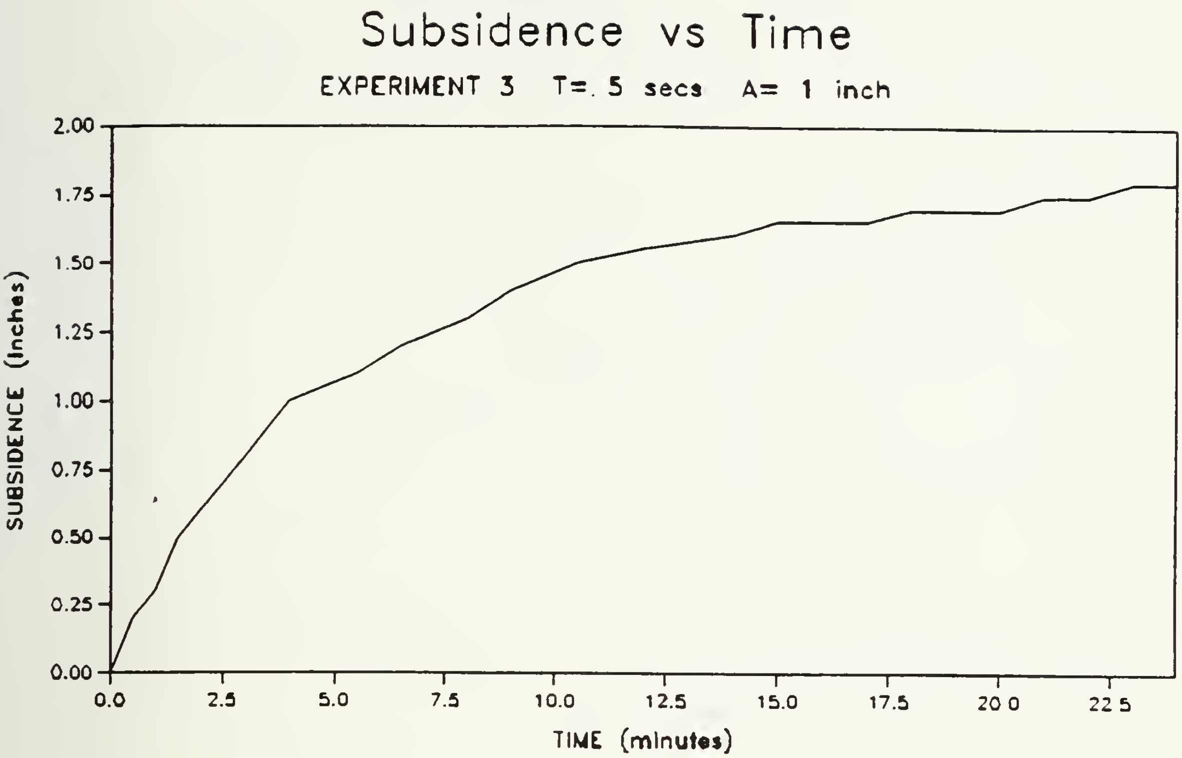
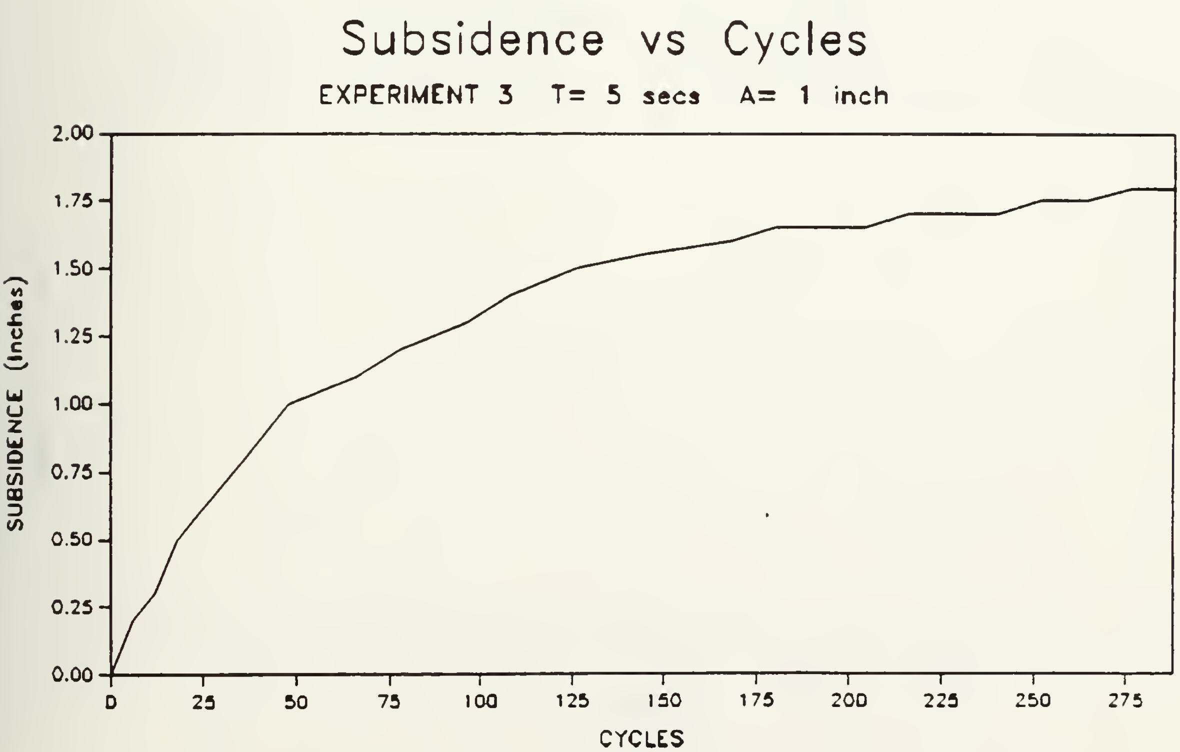

Subsidence vs Cycles
EXPERIMENT 2 T= 20 secs A= 1 inch
SUBSIDENCE (inches)
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
50
100
150
200
250
300
CYCLES

FIGURE 2

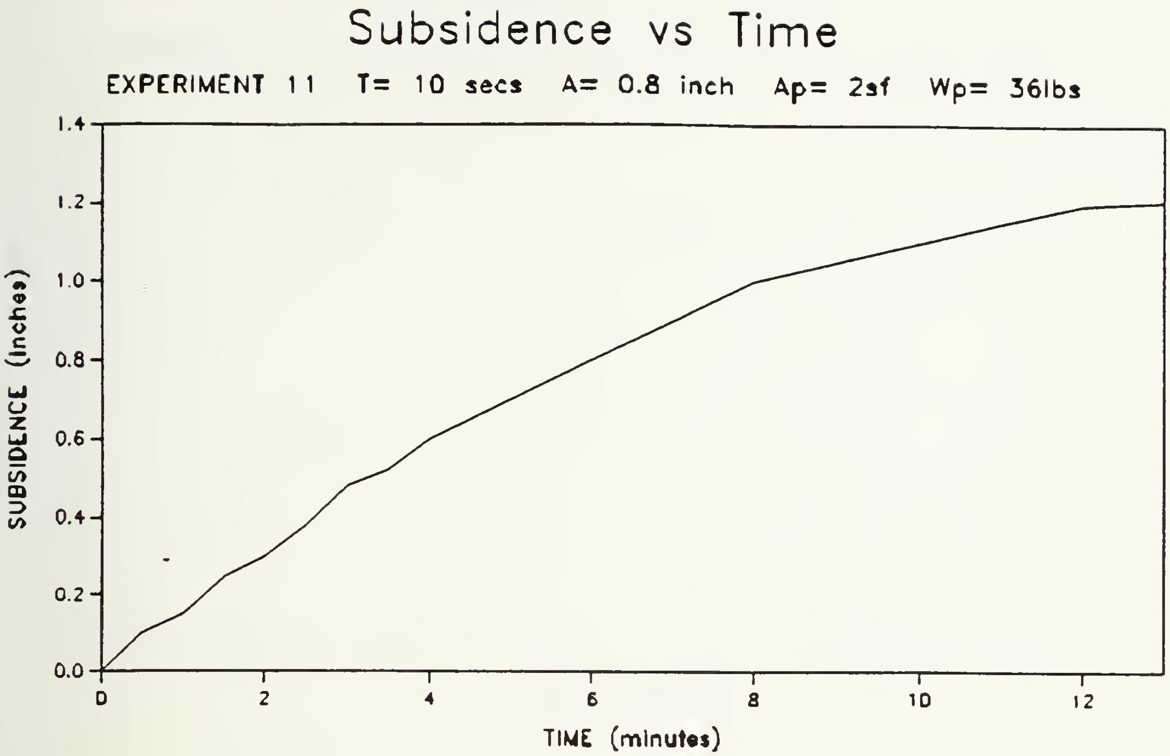


Subsidence vs Time
EXPERIMENT 3 T=.5 secs A= 1 inch
SUBSIDENCE (inches)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
TIME (minutes)



Subsidence vs Cycles
EXPERIMENT 3 T= 5 secs A= 1 inch
SUBSIDENCE (inches)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
25
50
75
100
125
150
175
200
225
250
275
CYCLES

FIGURE 3


Subsidence vs Time
EXPERIMENT 11 T= 10 secs A= 0.8 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (inches)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
12
TIME (minutes)

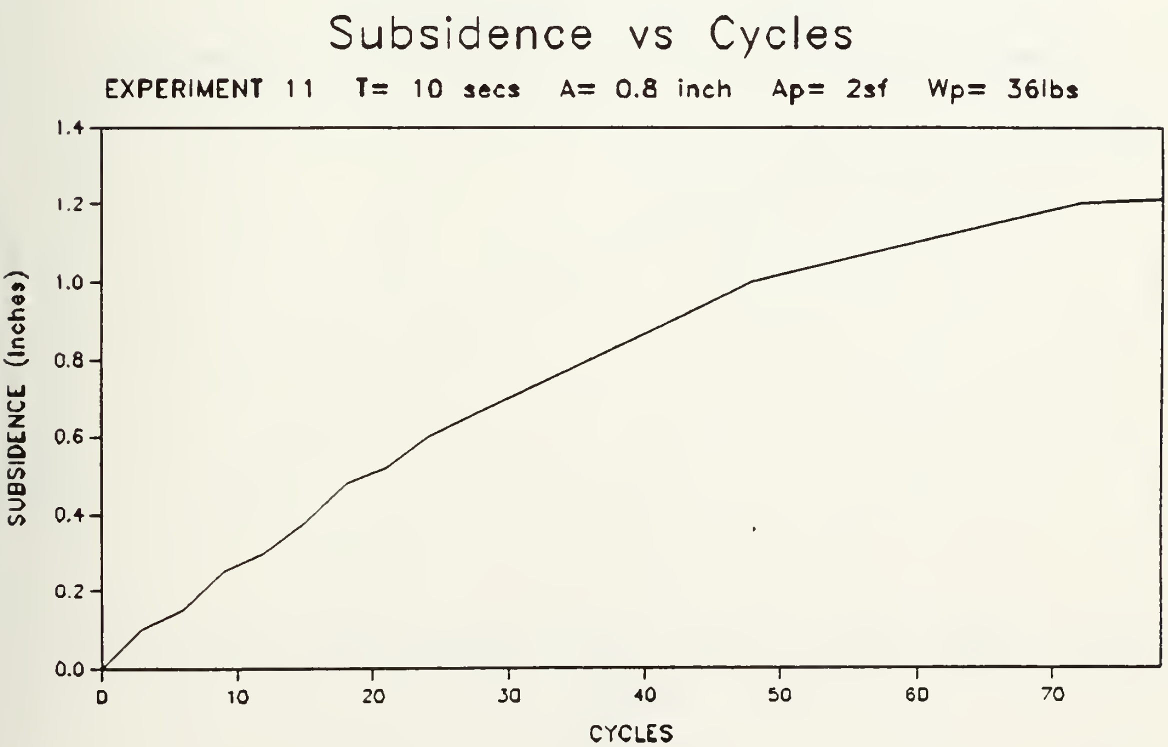
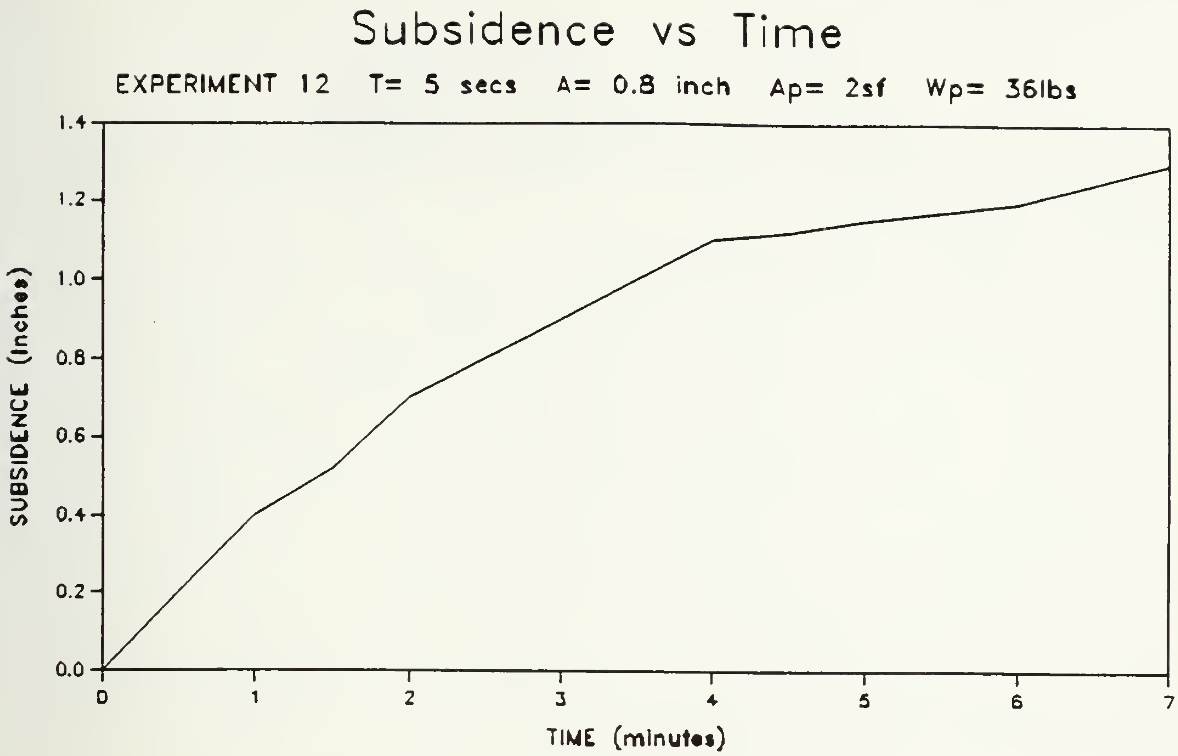

Subsidence vs Cycles
EXPERIMENT 11 T= 10 secs A= 0.8 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (inches)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
70
CYCLES

FIGURE 11


Subsidence vs Time
EXPERIMENT 12 T= 5 secs A= 0.8 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (inches)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
TIME (minutes)

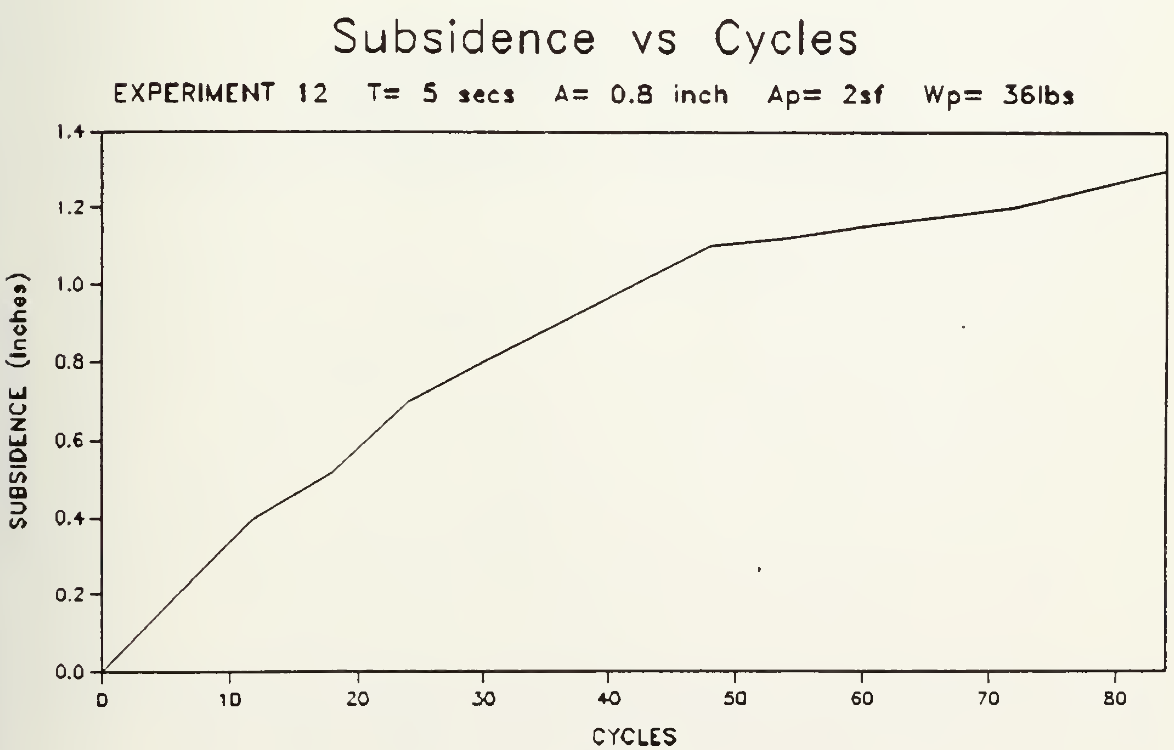
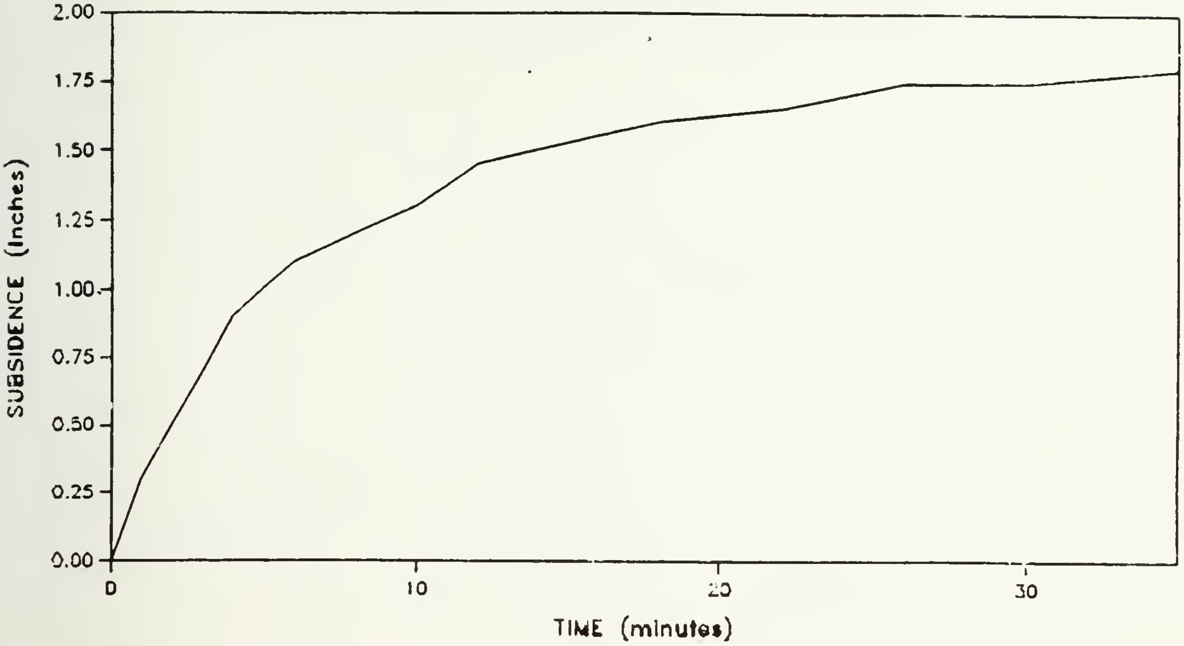

Subsidence vs Cycles
EXPERIMENT 12 T= 5 secs A= 0.8 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (inches)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
70
80
CYCLES

FIGURE 12

Subsidence vs Time

EXPERIMENT 1 T= 10 secs A= 1 inch



Subsidence vs Cycles

EXPERIMENT 1 T= 10 secs A= 1 inch

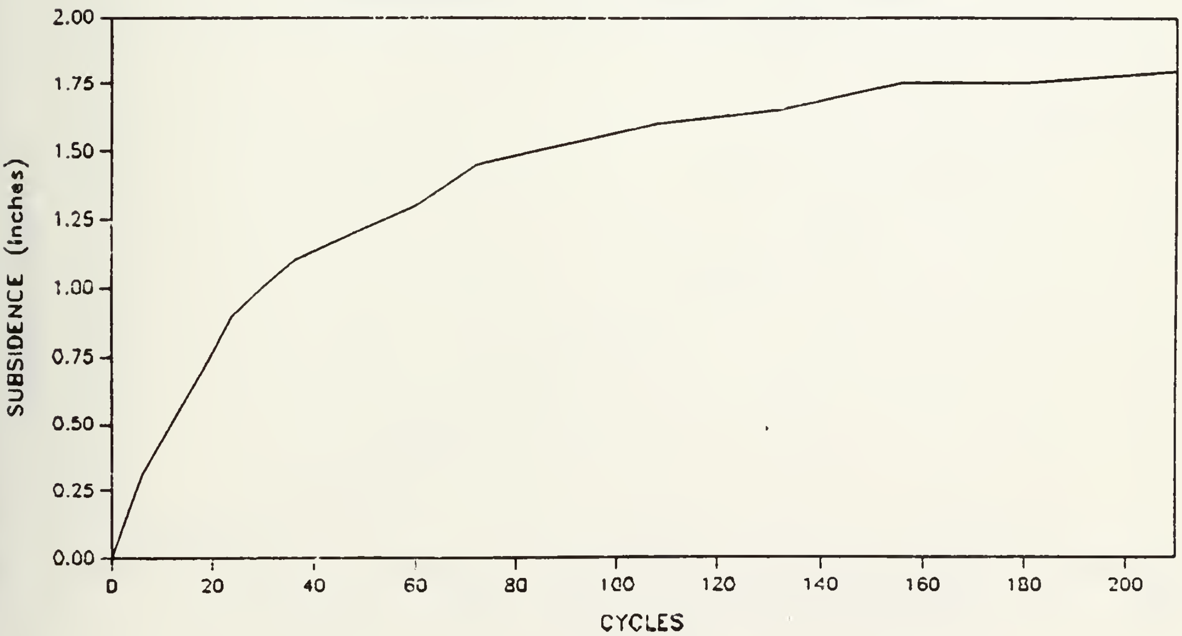
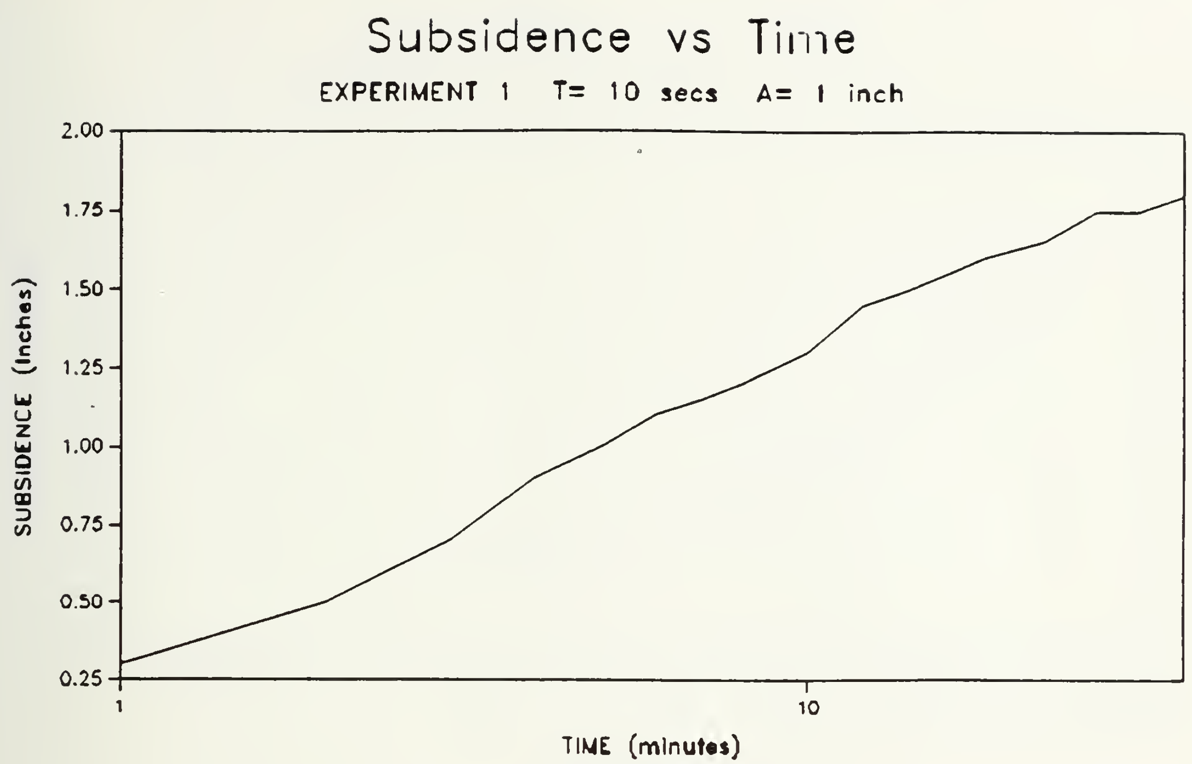
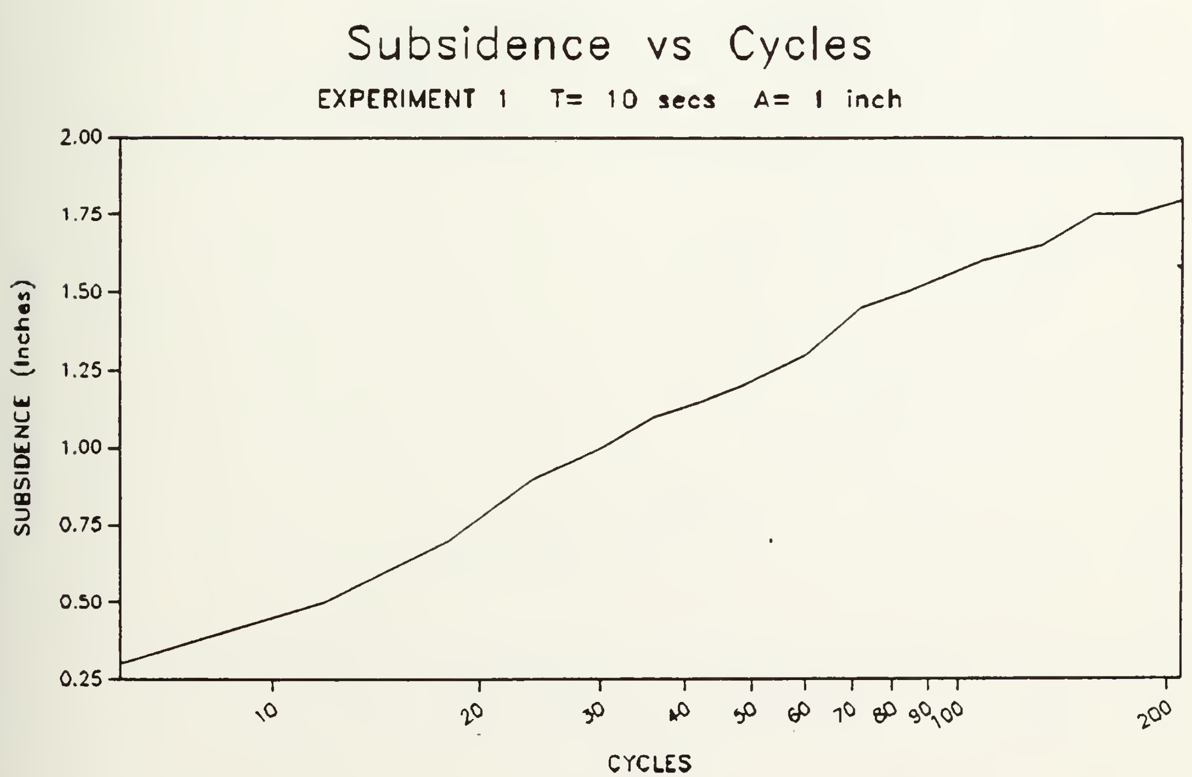


FIGURE 1

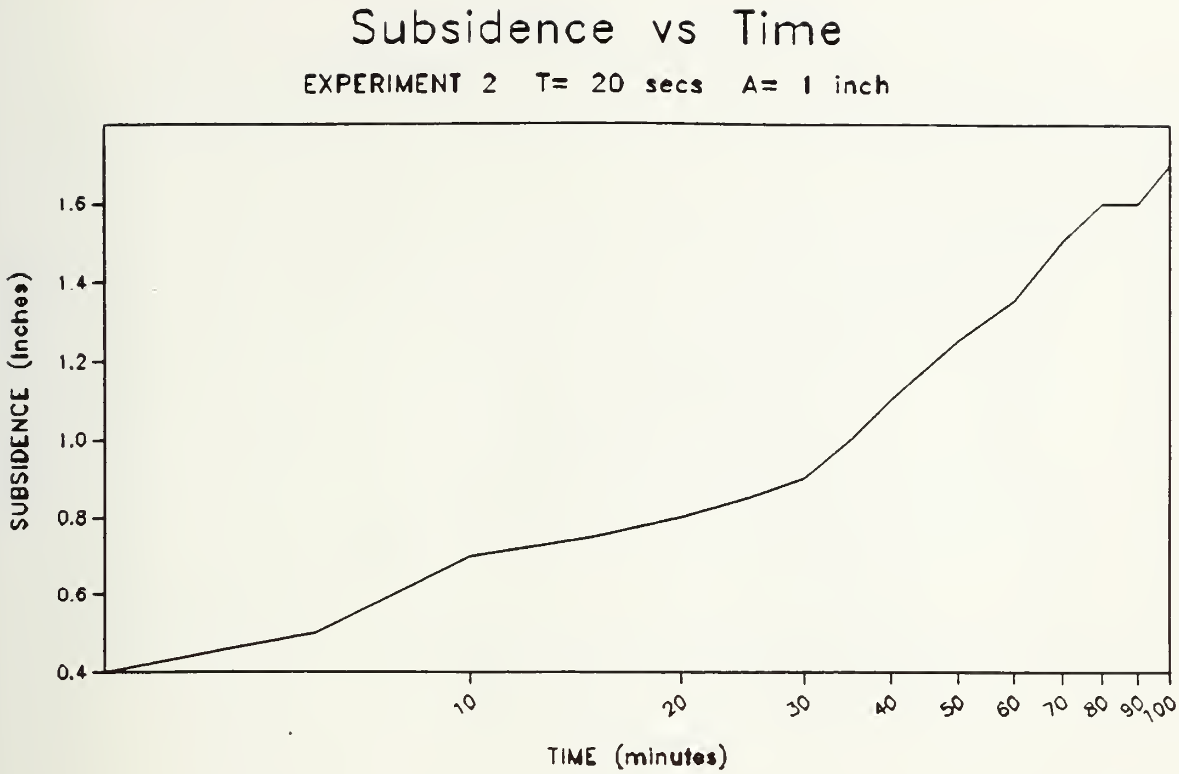


Subsidence vs Time
EXPERIMENT 1 T= 10 secs A= 1 inch
SUBSIDENCE (Inches)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
1
10
TIME (minutes)



Subsidence vs Cycles
EXPERIMENT 1 T= 10 secs A= 1 inch
SUBSIDENCE (Inches)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
10
20
30
40
50
60
70
80
90
100
200
CYCLES

FIGURE 13


Subsidence vs Time
EXPERIMENT 2 T= 20 secs A= 1 inch
SUBSIDENCE (inches)
0.4
0.6
0.8
1.0
1.2
1.4
1.6
10
20
30
40
50
60
70
80
90
100
TIME (minutes)

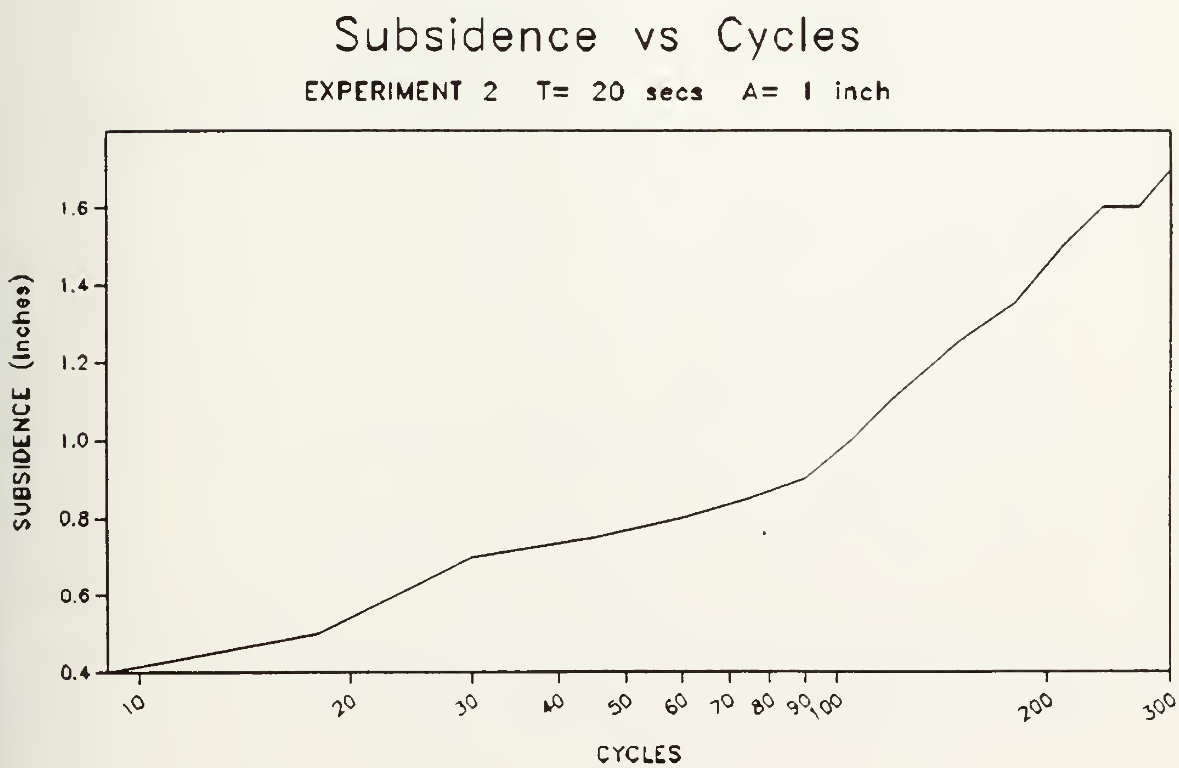
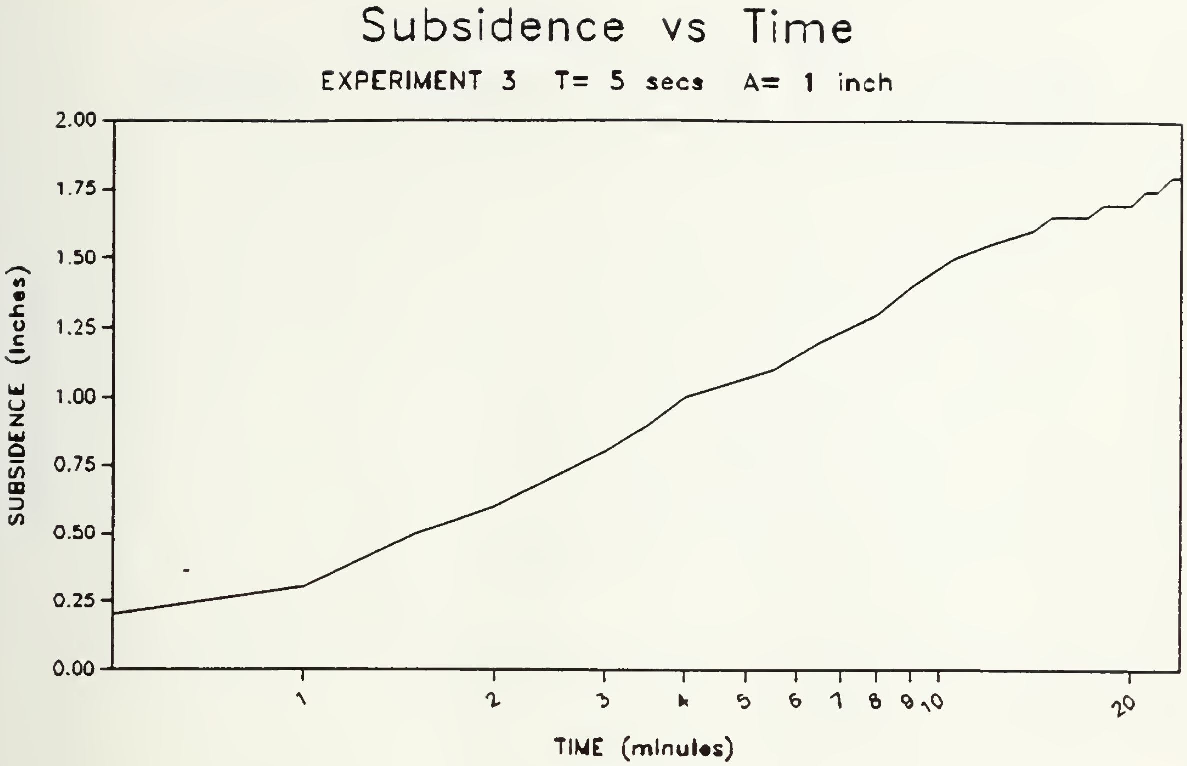

Subsidence vs Cycles
EXPERIMENT 2 T= 20 secs A= 1 inch
SUBSIDENCE (inches)
0.4
0.6
0.8
1.0
1.2
1.4
1.6
10
20
30
40
50
60
70
80
90
100
200
300
CYCLES

FIGURE 14


Subsidence vs Time
EXPERIMENT 3 T= 5 secs A= 1 inch
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SUBSIDENCE (Inches)
1
2
3
4
5
6
7
8
9
10
20
TIME (minutes)

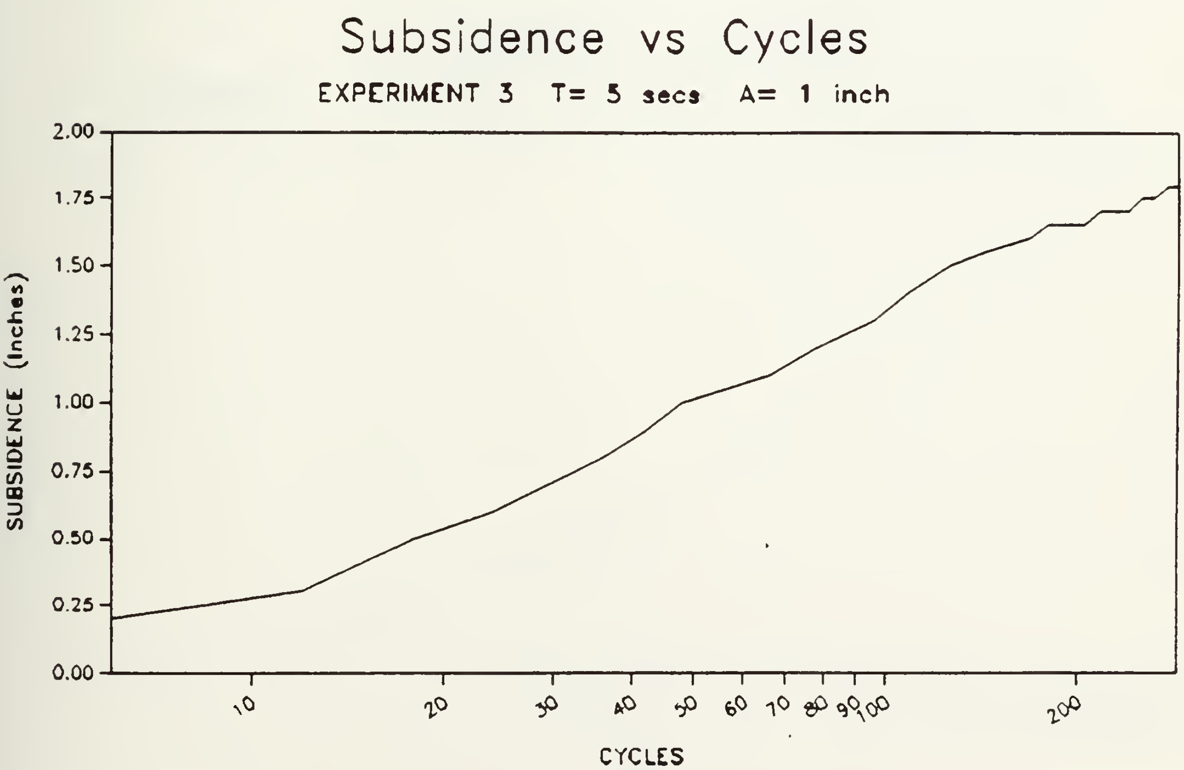
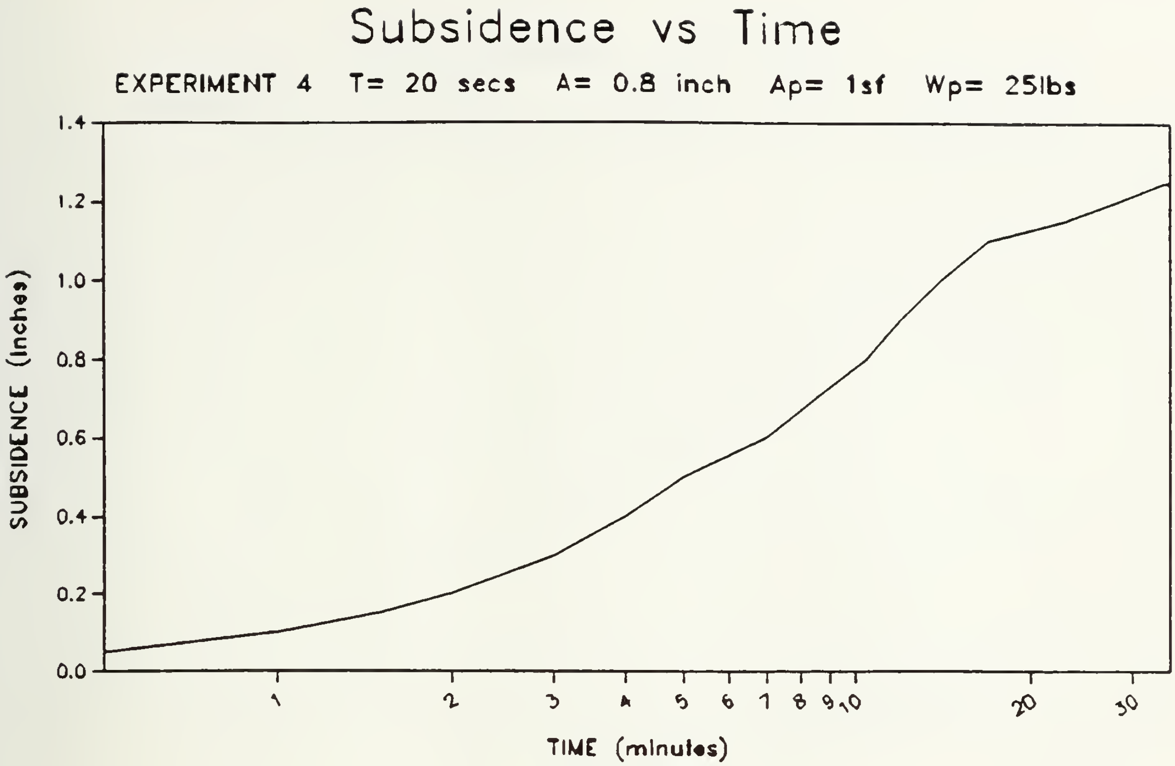

Subsidence vs Cycles
EXPERIMENT 3 T= 5 secs A= 1 inch
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
SUBSIDENCE (Inches)
10
20
30
40
50
60
70
80
90
100
200
CYCLES

FIGURE 15


Subsidence vs Time
EXPERIMENT 4 T= 20 secs A= 0.8 inch Ap= 1sf Wp= 25lbs
SUBSIDENCE (Inches)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1 2 3 4 5 6 7 8 9 10 20 30
TIME (minutes)

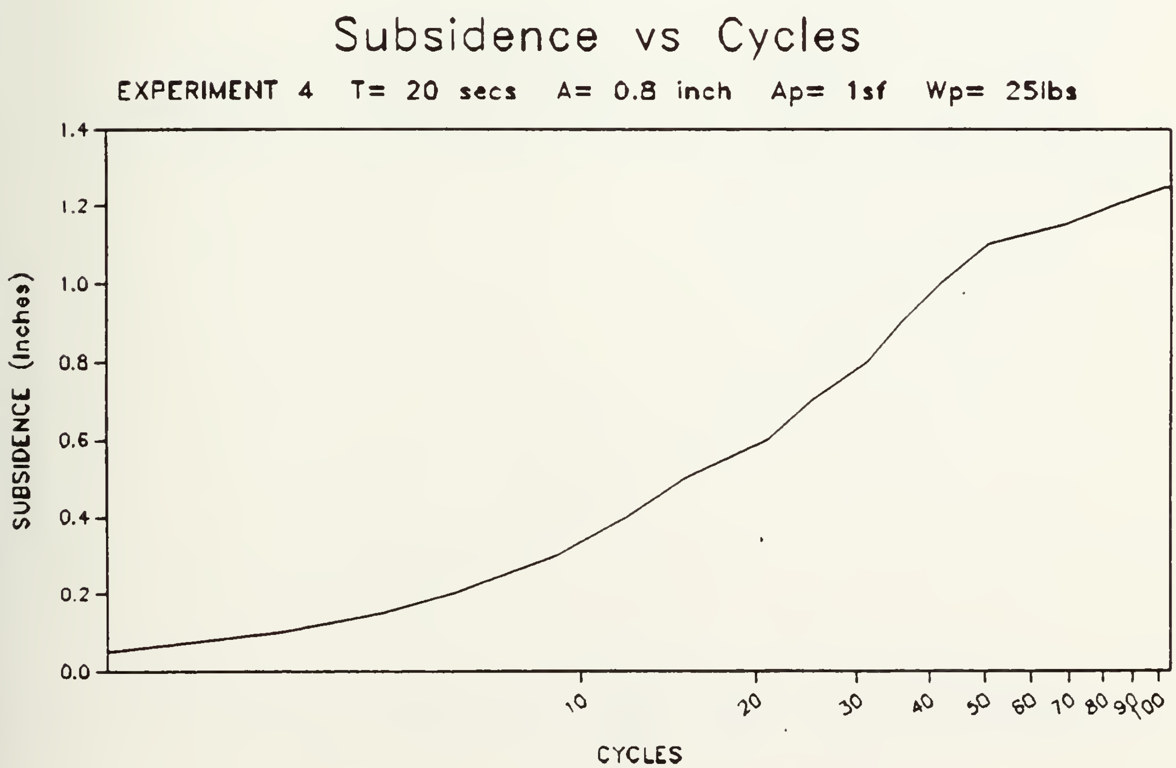
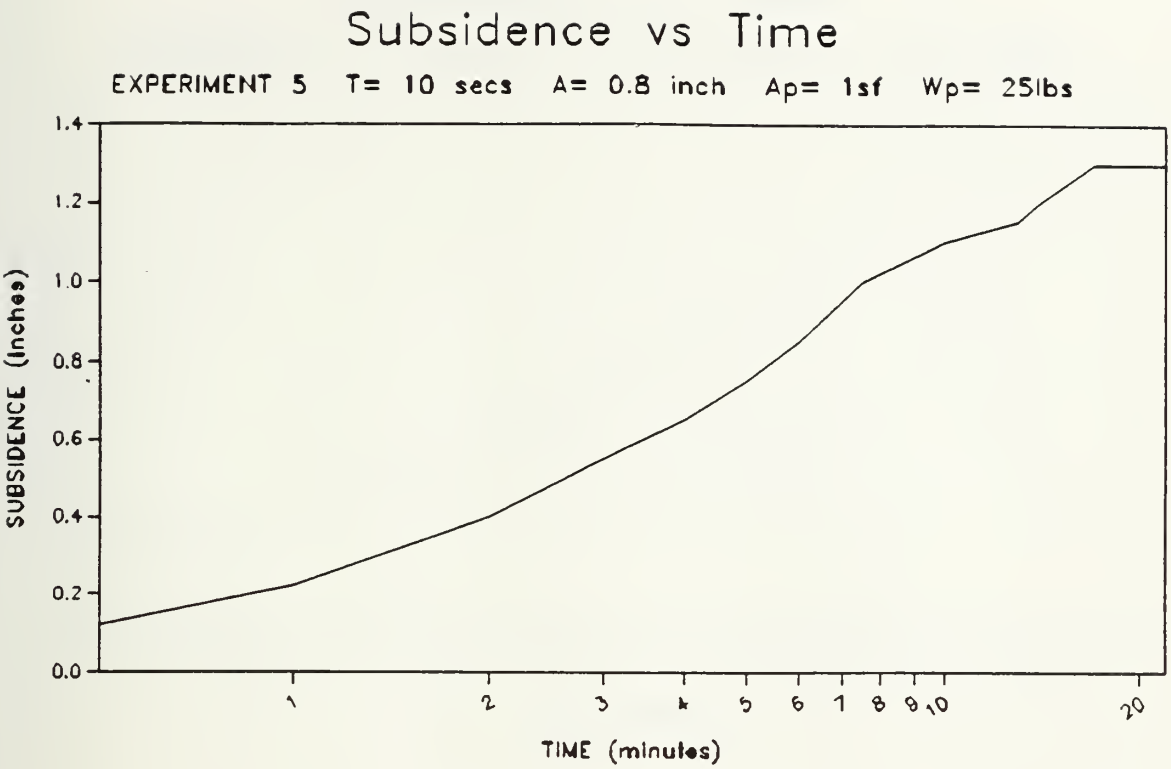

Subsidence vs Cycles
EXPERIMENT 4 T= 20 secs A= 0.8 inch Ap= 1sf Wp= 25lbs
SUBSIDENCE (Inches)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
10 20 30 40 50 60 70 80 90 100
CYCLES

FIGURE 16


Subsidence vs Time
EXPERIMENT 5 T= 10 secs A= 0.8 inch Ap= 1sf Wp= 25lbs
SUBSIDENCE (inches)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
4
5
6
7
8
9
10
20
TIME (minutes)

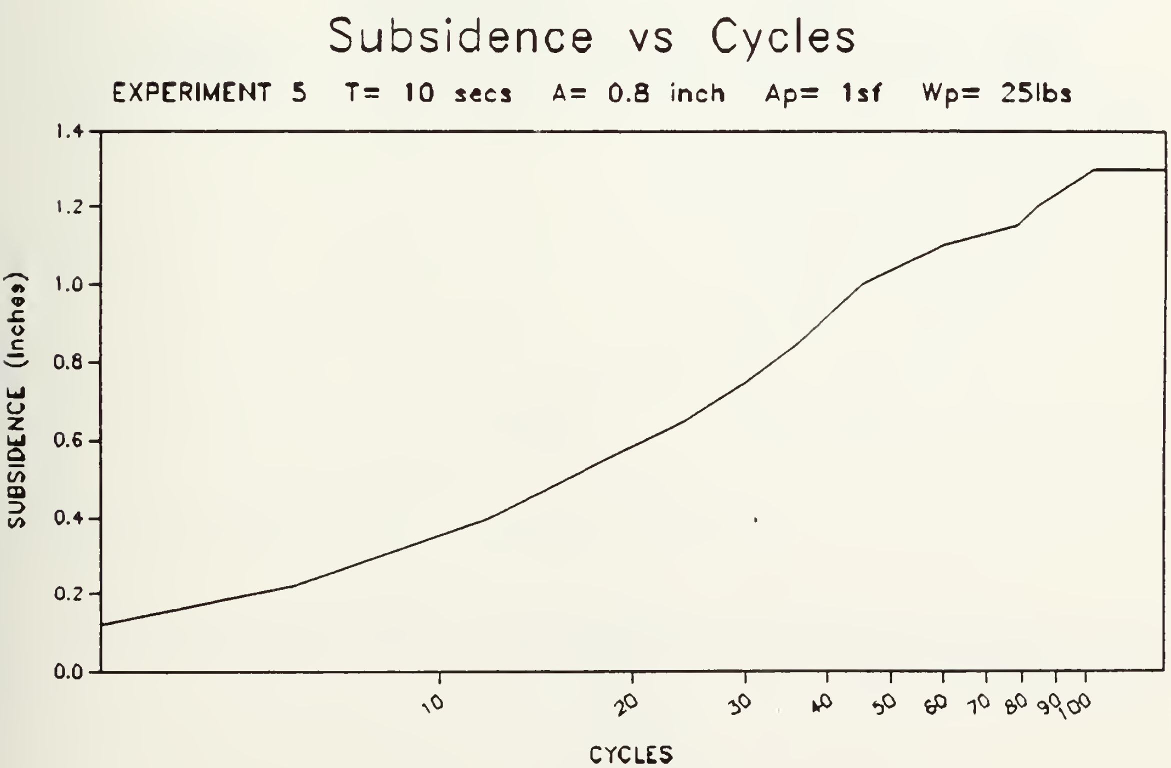
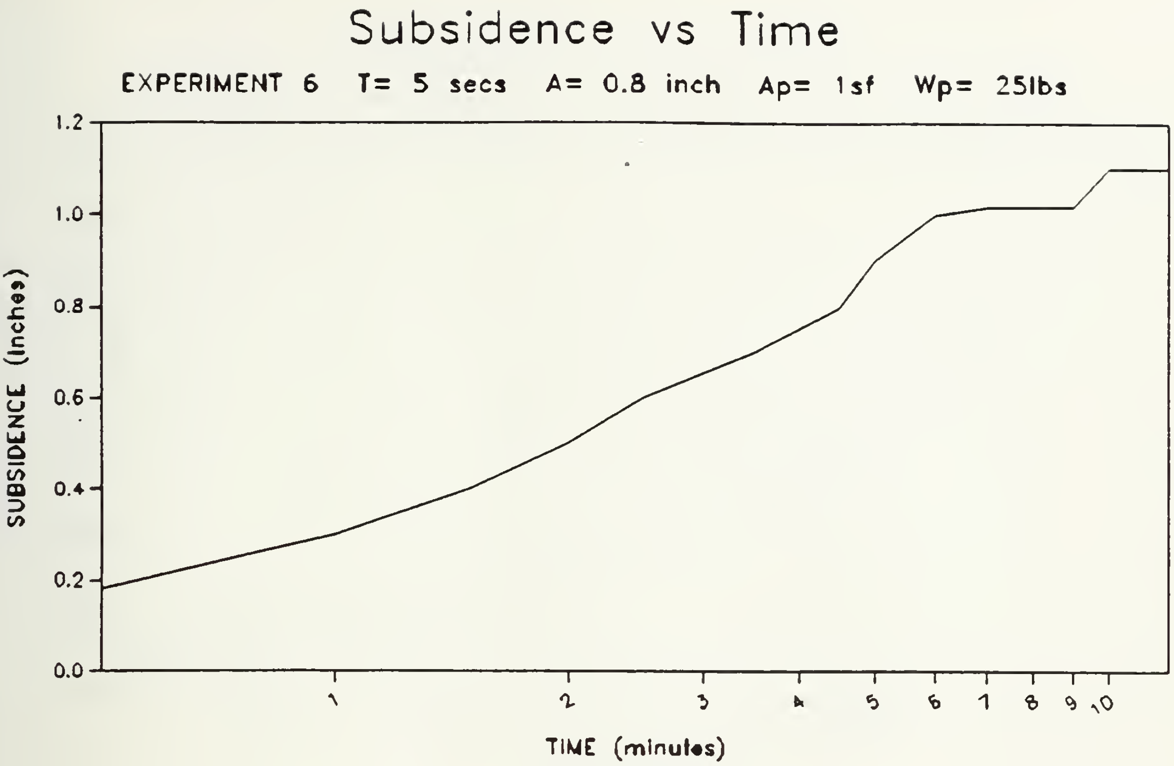

Subsidence vs Cycles
EXPERIMENT 5 T= 10 secs A= 0.8 inch Ap= 1sf Wp= 25lbs
SUBSIDENCE (inches)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
10
20
30
40
50
60
70
80
90
100
CYCLES

FIGURE 17


Subsidence vs Time
EXPERIMENT 6 T= 5 secs A= 0.8 inch Ap= 1sf Wp= 25lbs
SUBSIDENCE (Inches)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
4
5
6
7
8
9
10
TIME (minutes)

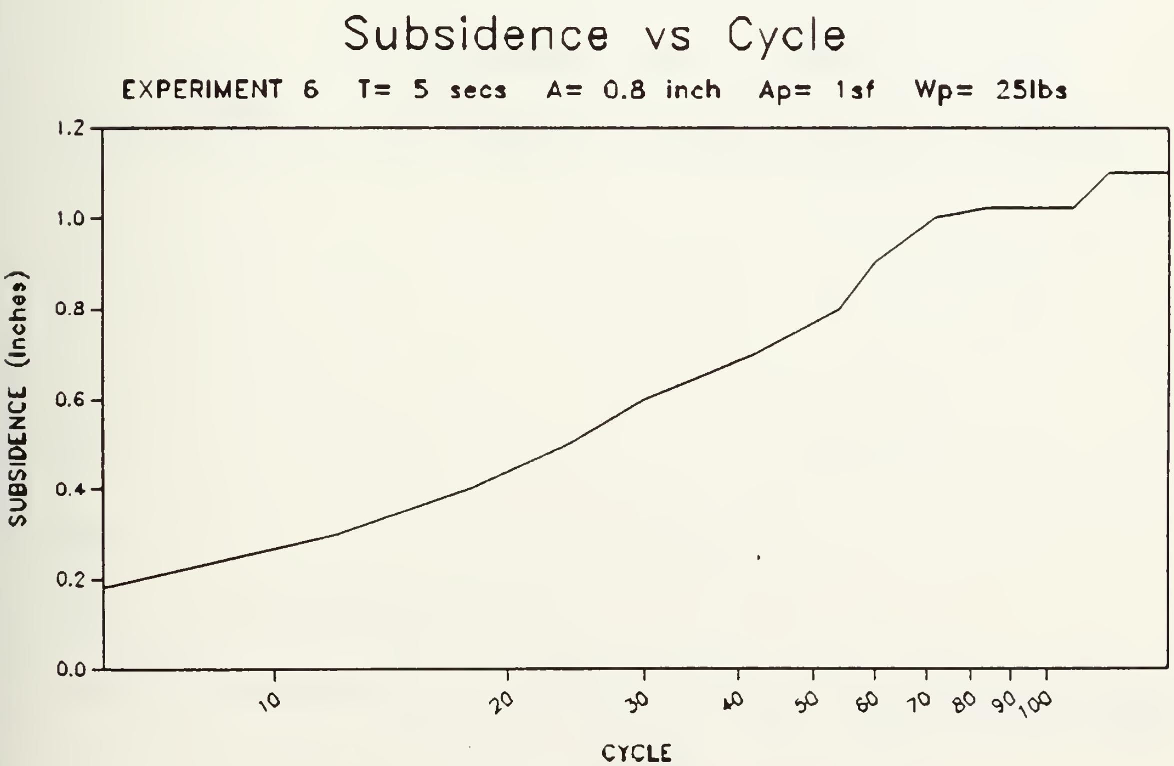
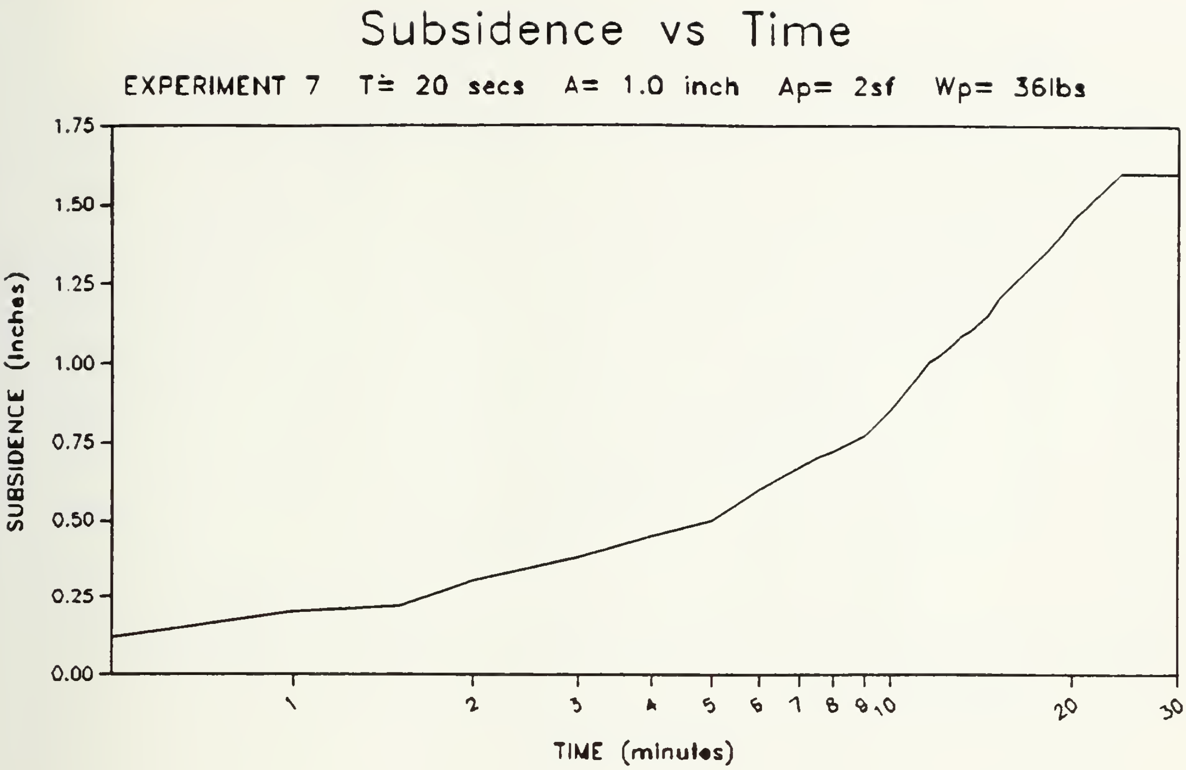
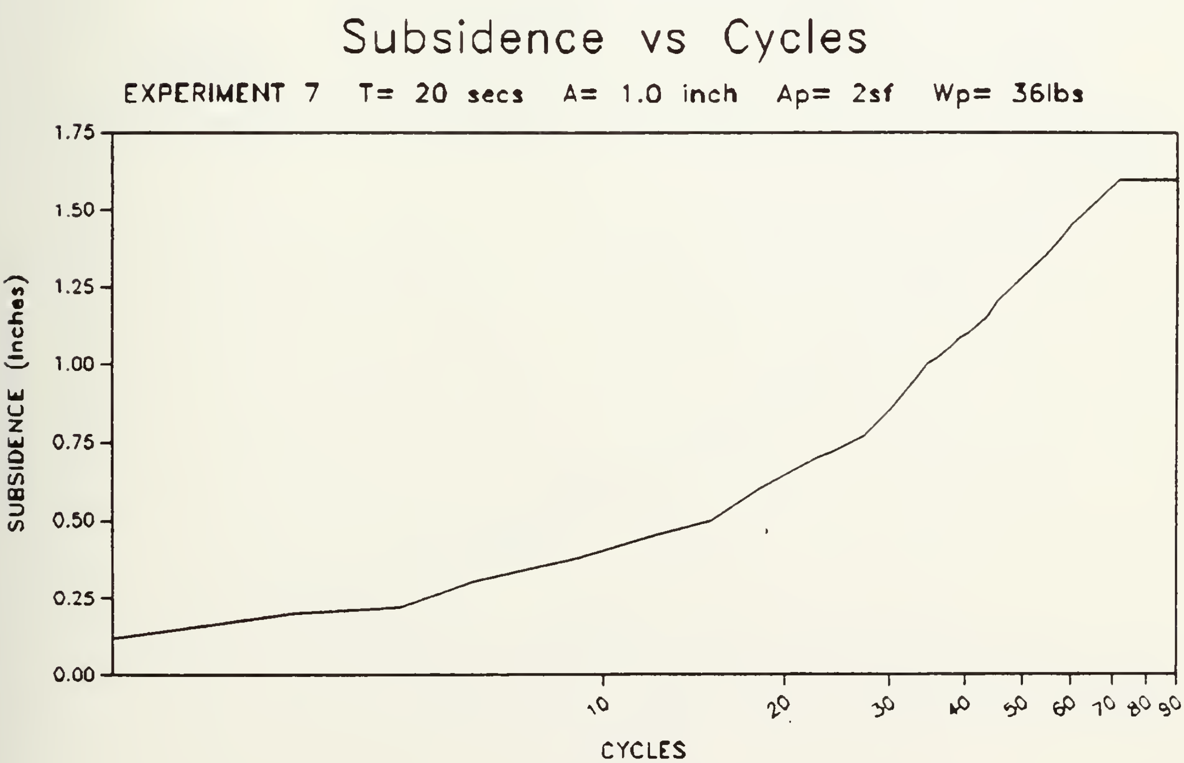

Subsidence vs Cycle
EXPERIMENT 6 T= 5 secs A= 0.8 inch Ap= 1sf Wp= 25lbs
SUBSIDENCE (Inches)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
10
20
30
40
50
60
70
80
90
100
CYCLE

FIGURE 18

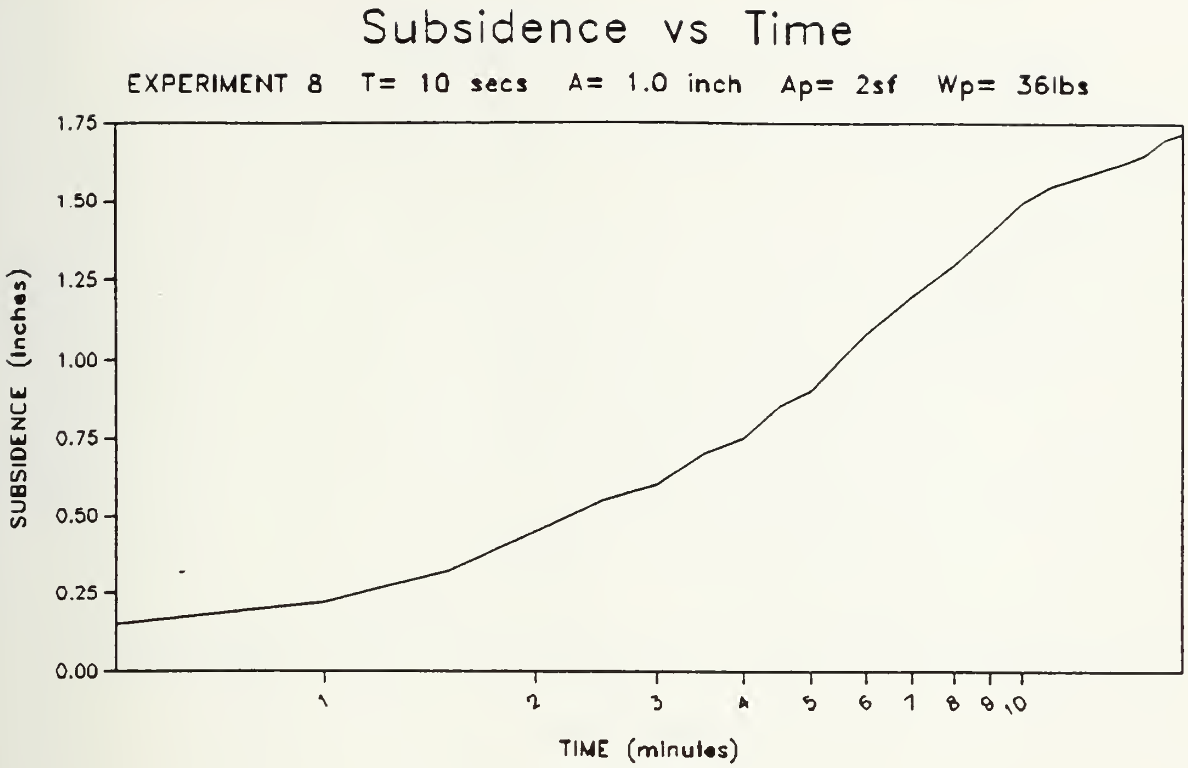


Subsidence vs Time
EXPERIMENT 7 T= 20 secs A= 1.0 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (inches)
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
1 2 3 4 5 6 7 8 9 10 20 30
TIME (minutes)



Subsidence vs Cycles
EXPERIMENT 7 T= 20 secs A= 1.0 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (inches)
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
10 20 30 40 50 60 70 80 90
CYCLES

FIGURE 19


Subsidence vs Time
EXPERIMENT 8 T= 10 secs A= 1.0 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (inches)
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
1
2
3
4
5
6
7
8
9
10
TIME (minutes)

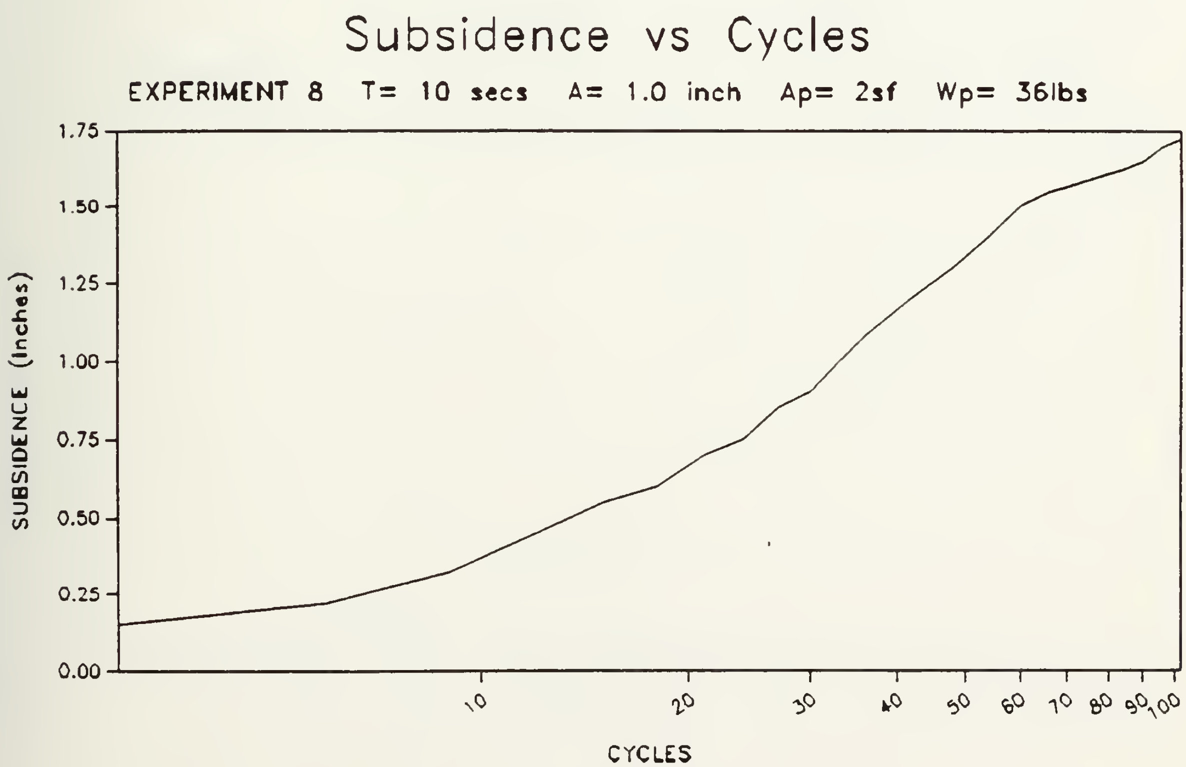
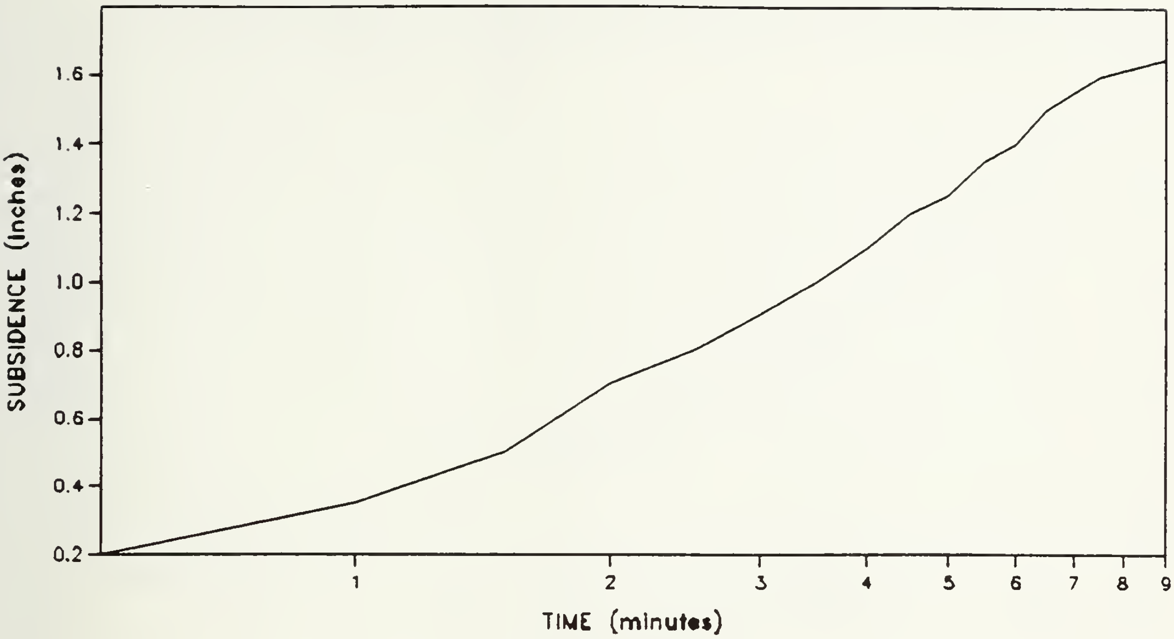

Subsidence vs Cycles
EXPERIMENT 8 T= 10 secs A= 1.0 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (inches)
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
10
20
30
40
50
60
70
80
90
100
CYCLES

FIGURE 20

Subsidence vs Time

EXPERIMENT 9 T= 5 secs A= 1.0 inch Ap= 2sf Wp= 36lbs



Subsidence vs Cycles

EXPERIMENT 9 T= 5 secs A= 1.0 inch Ap= 2sf Wp= 36lbs

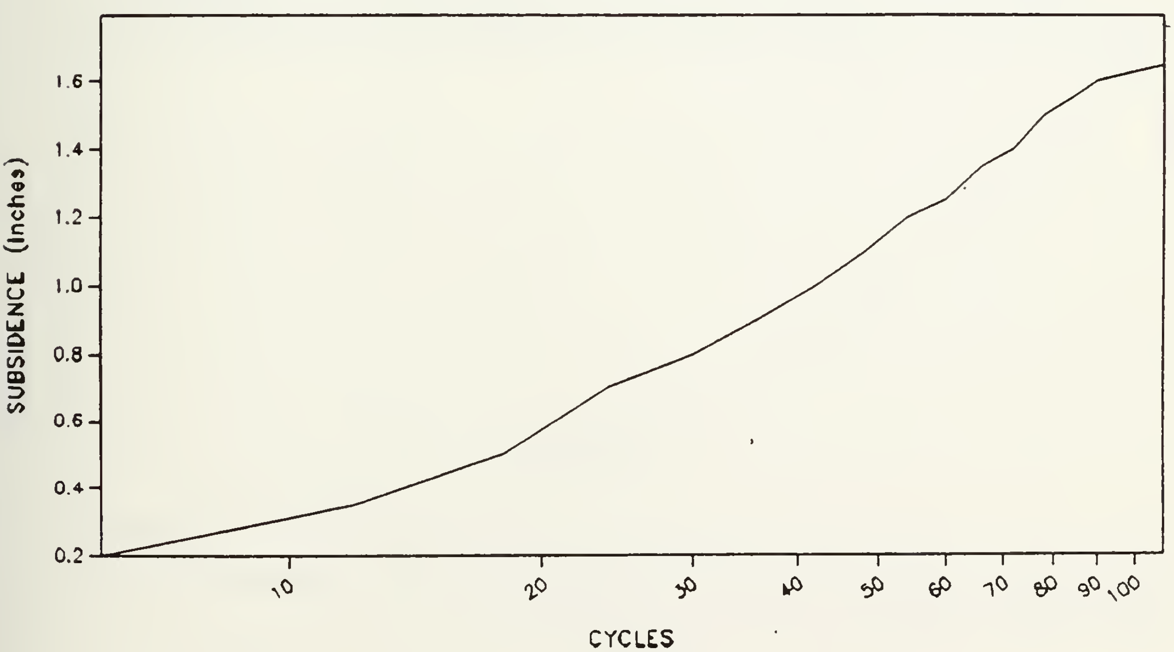
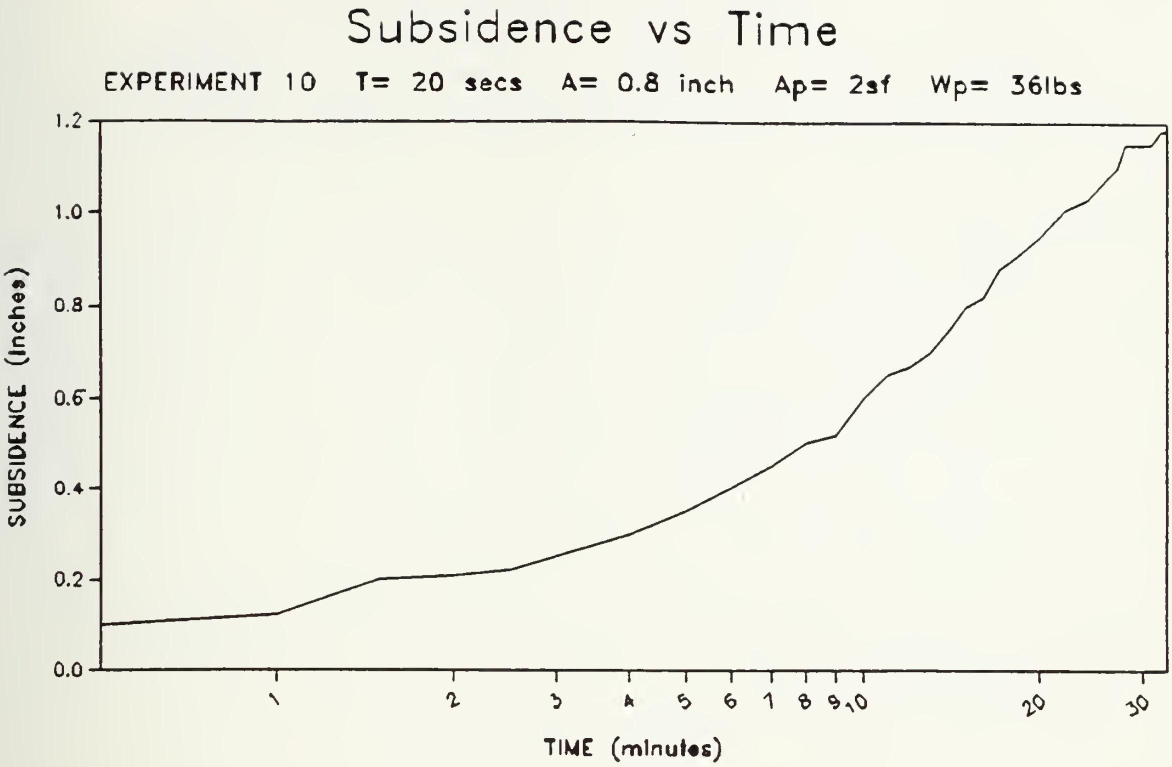


FIGURE 21


Subsidence vs Time
EXPERIMENT 10 T= 20 secs A= 0.8 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (inches)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1
2
3
4
5
6
7
8
9
10
20
30
TIME (minutes)

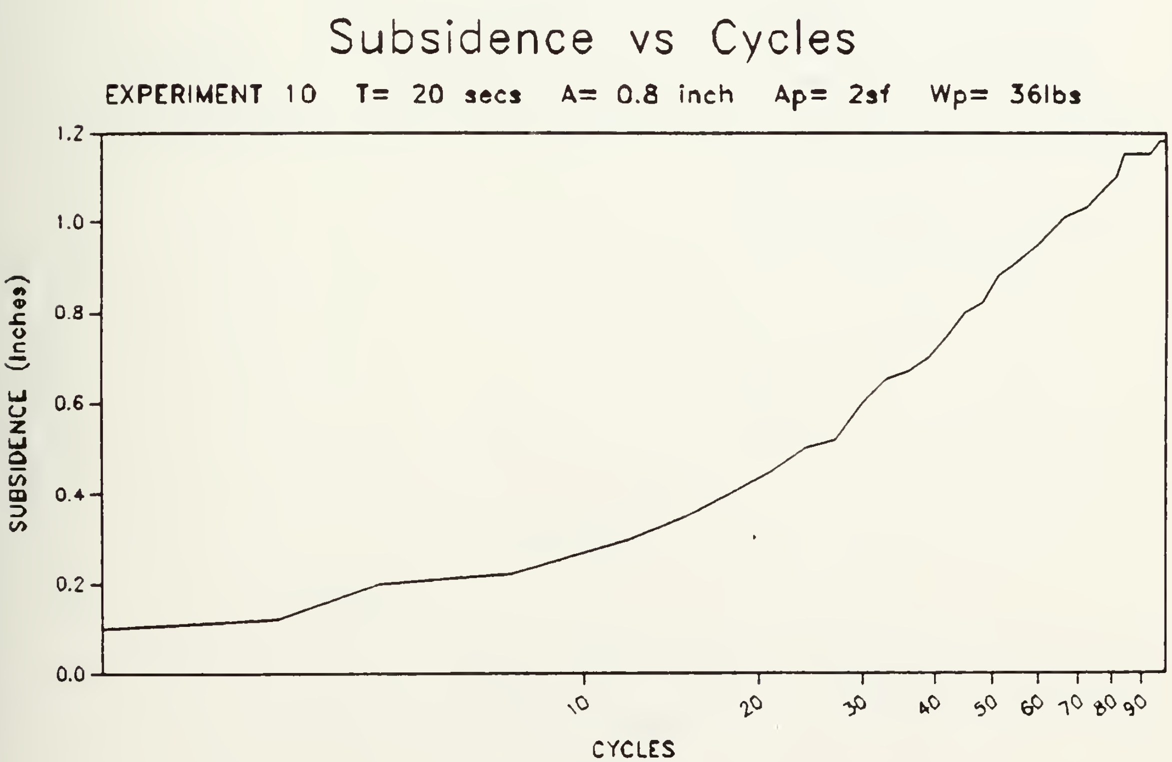
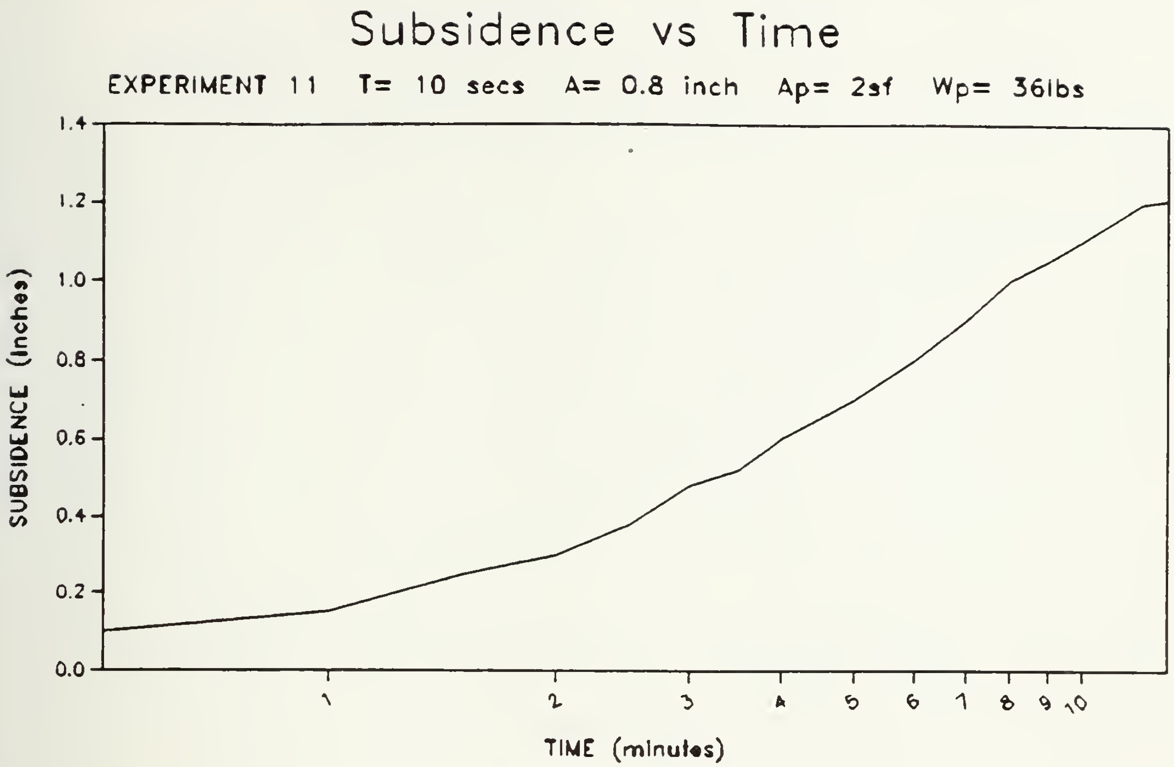

Subsidence vs Cycles
EXPERIMENT 10 T= 20 secs A= 0.8 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (inches)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
10
20
30
40
50
60
70
80
90
CYCLES

FIGURE 22


Subsidence vs Time
EXPERIMENT 11 T= 10 secs A= 0.8 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (inches)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
4
5
6
7
8
9
10
TIME (minutes)

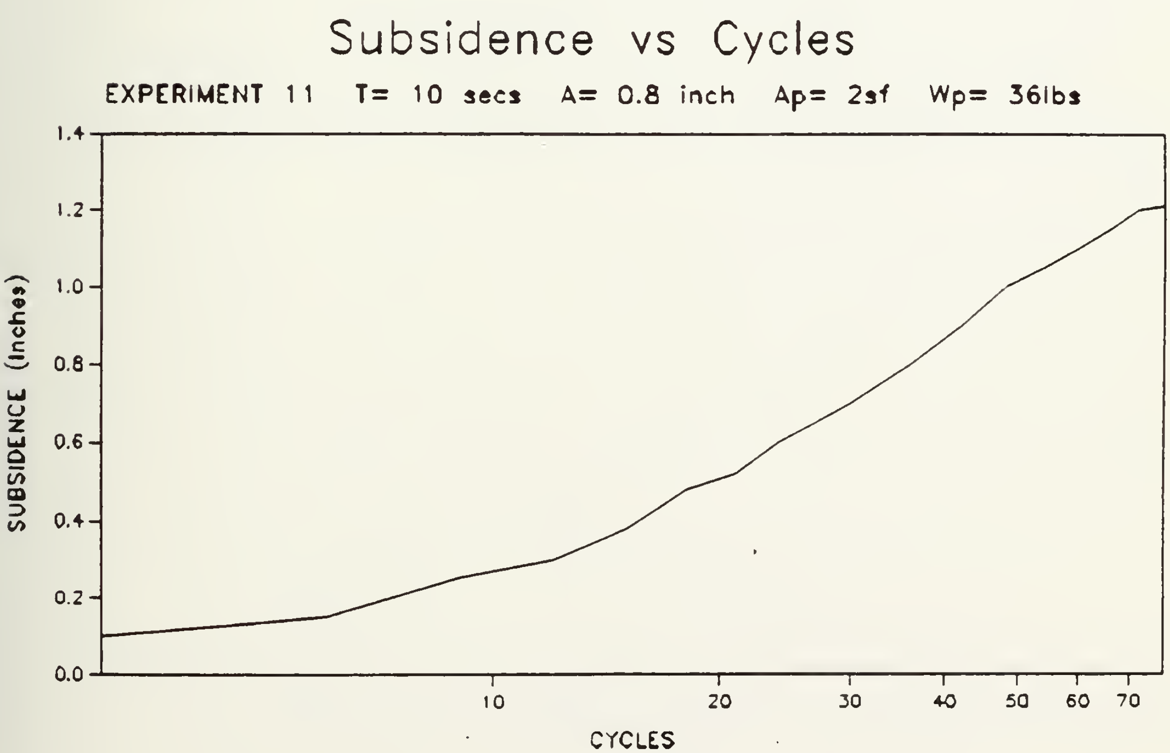
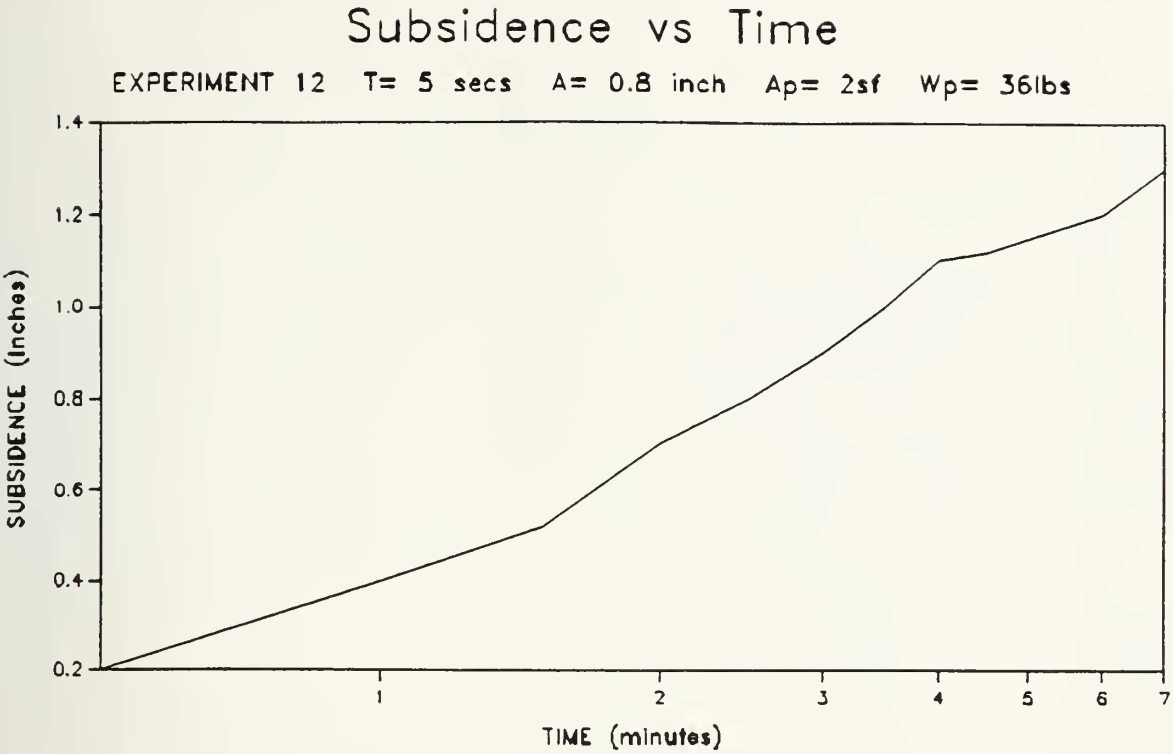

Subsidence vs Cycles
EXPERIMENT 11 T= 10 secs A= 0.8 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (inches)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
10
20
30
40
50
60
70
CYCLES

FIGURE 23


Subsidence vs Time
EXPERIMENT 12 T= 5 secs A= 0.8 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (inches)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
1
2
3
4
5
6
7
TIME (minutes)

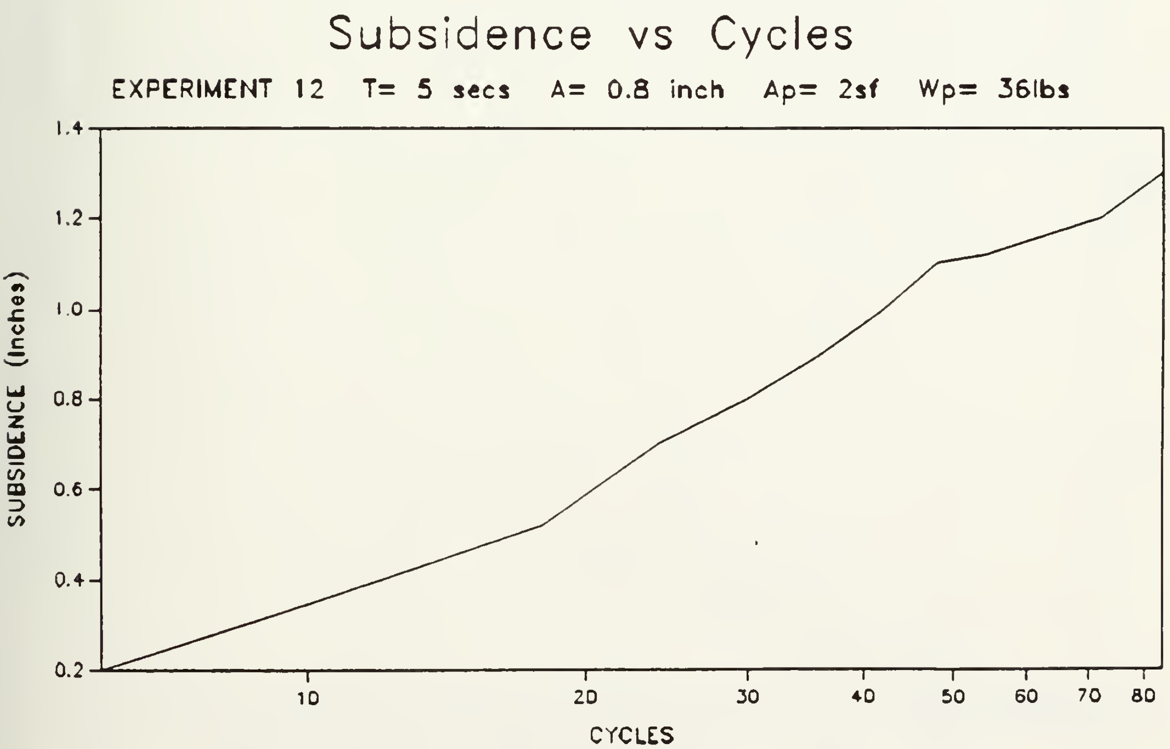

Subsidence vs Cycles
EXPERIMENT 12 T= 5 secs A= 0.8 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (inches)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
10
20
30
40
50
60
70
80
CYCLES

FIGURE 24

Subsidence vs Cycles

T = 20 secs; Experiments 7,4,10,& 2

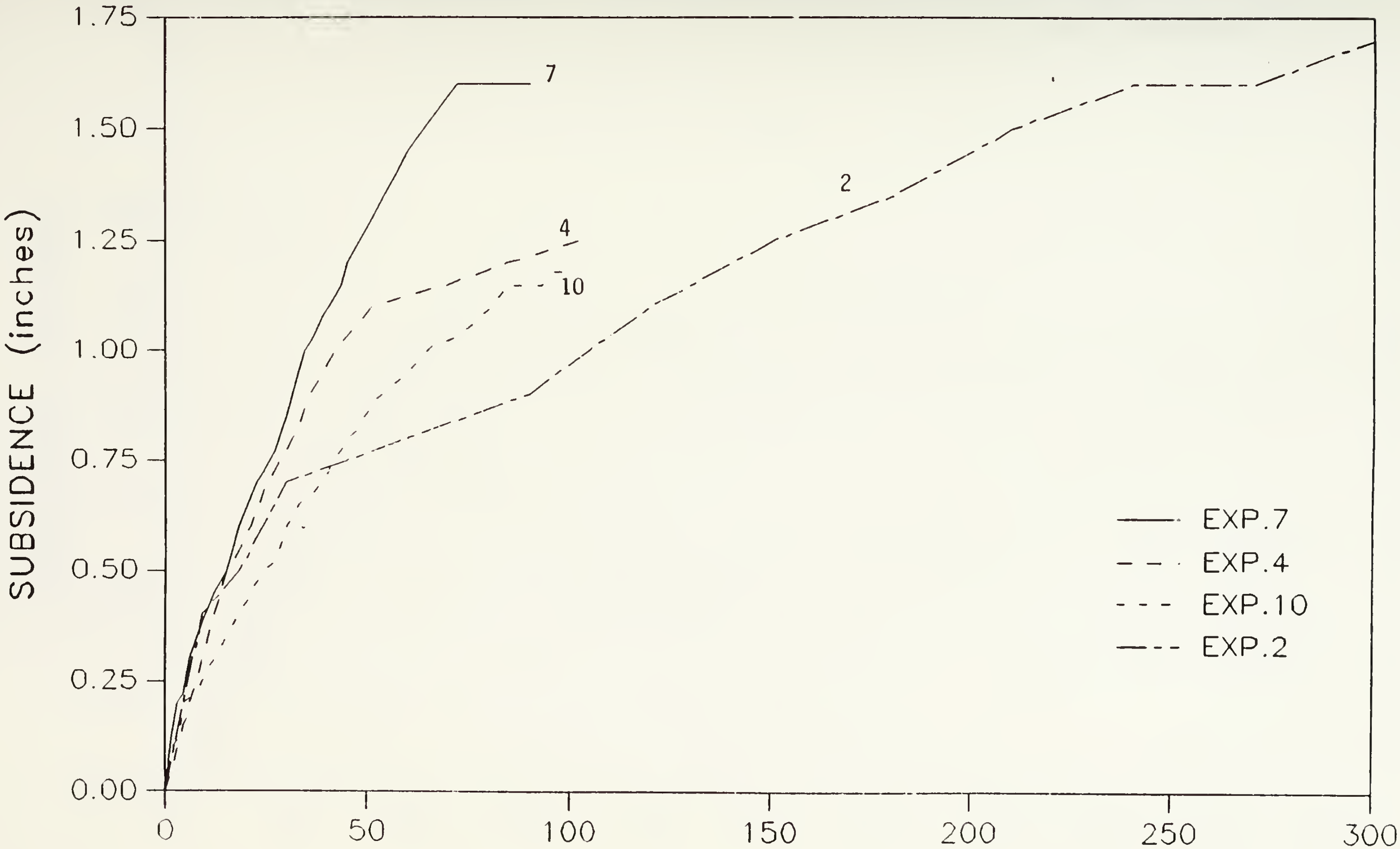


FIGURE 25

Subsidence vs Cycles

T = 10 secs; Experiments 8,1,11,& 5

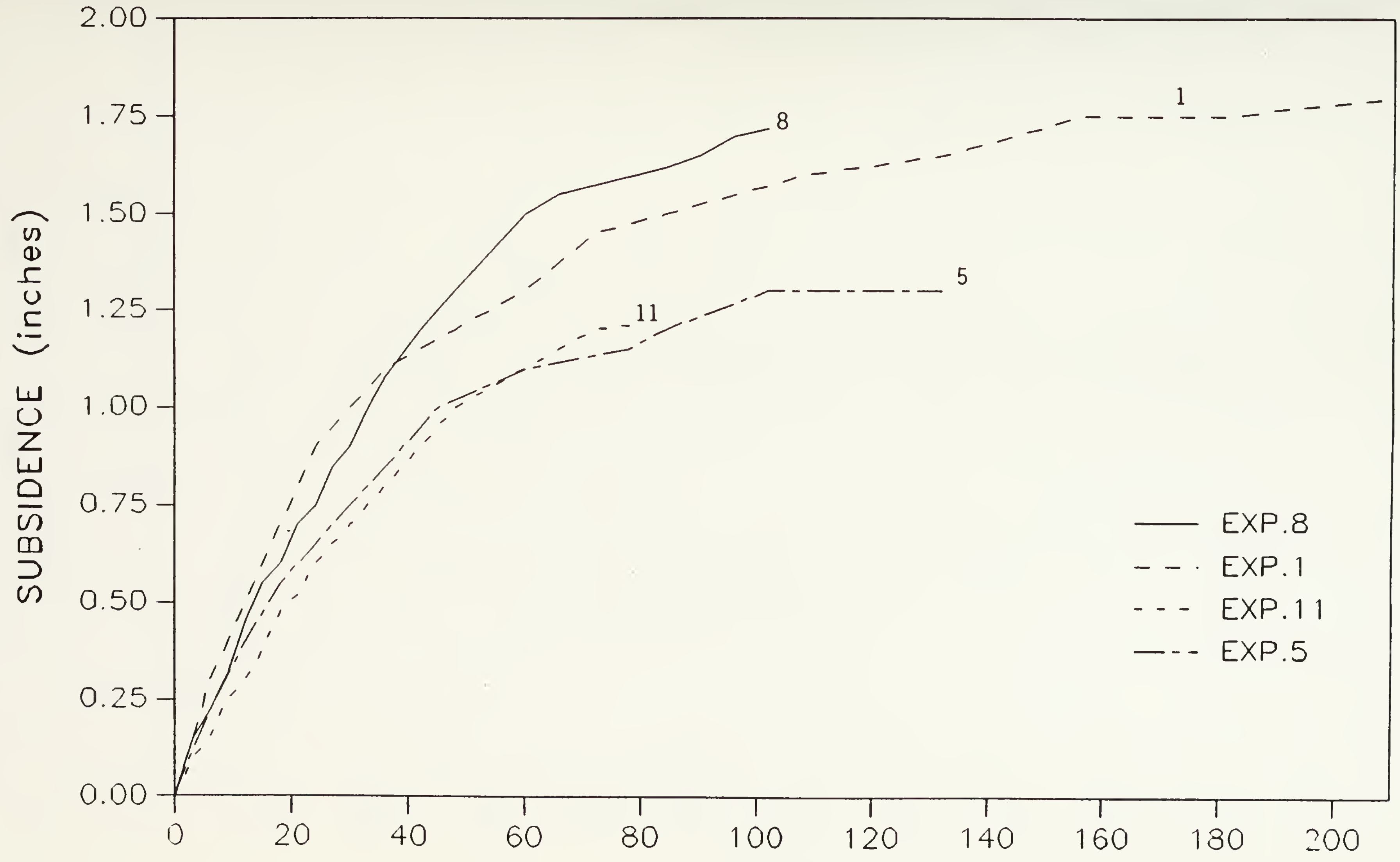


FIGURE 26

Subsidence vs Cycle

T = 5 secs; Experiments 9,3,12,& 6

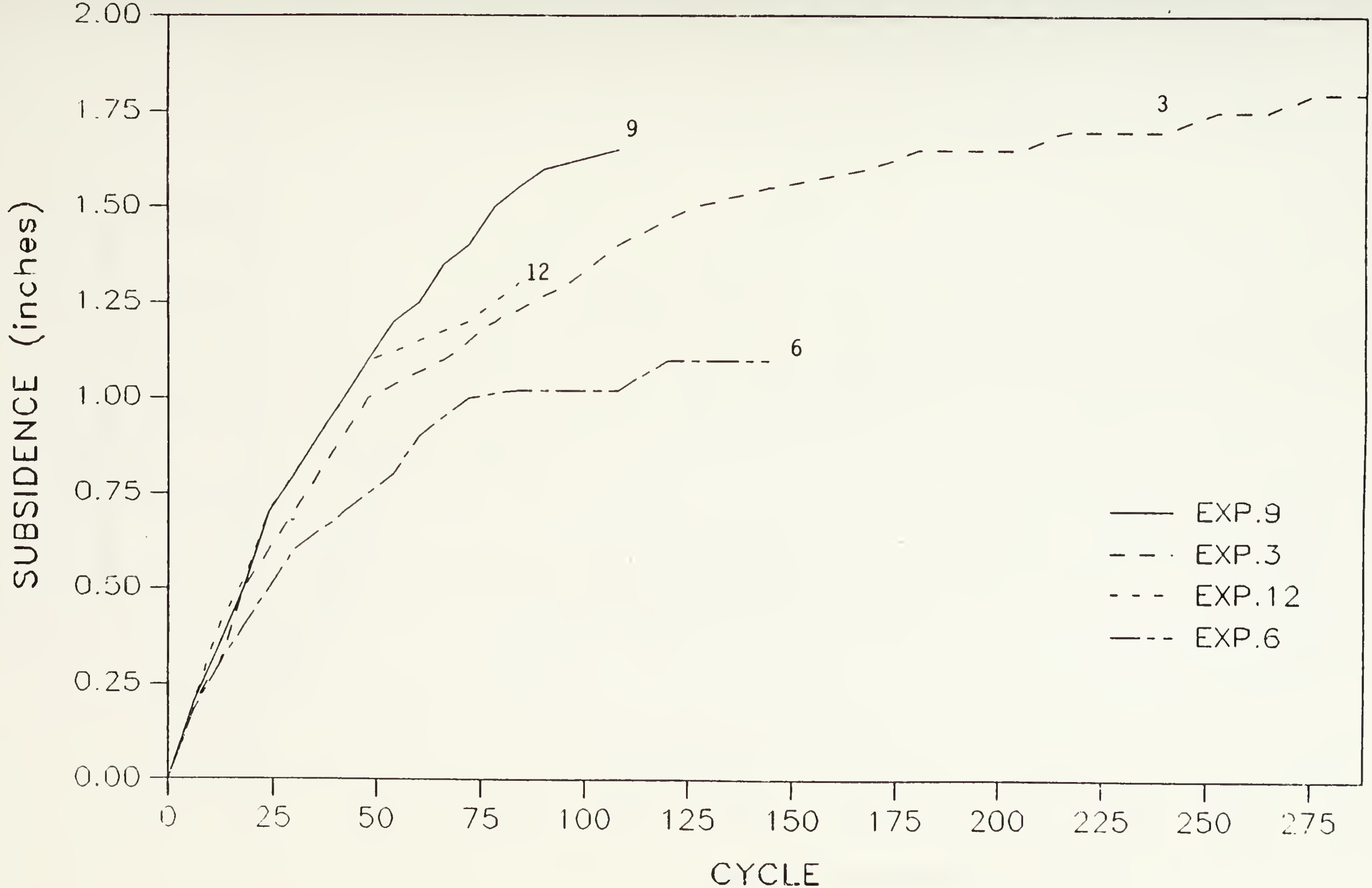


FIGURE 27

Subsidence Vs Time

T = 5 secs; Experiments 9,3,12,& 6

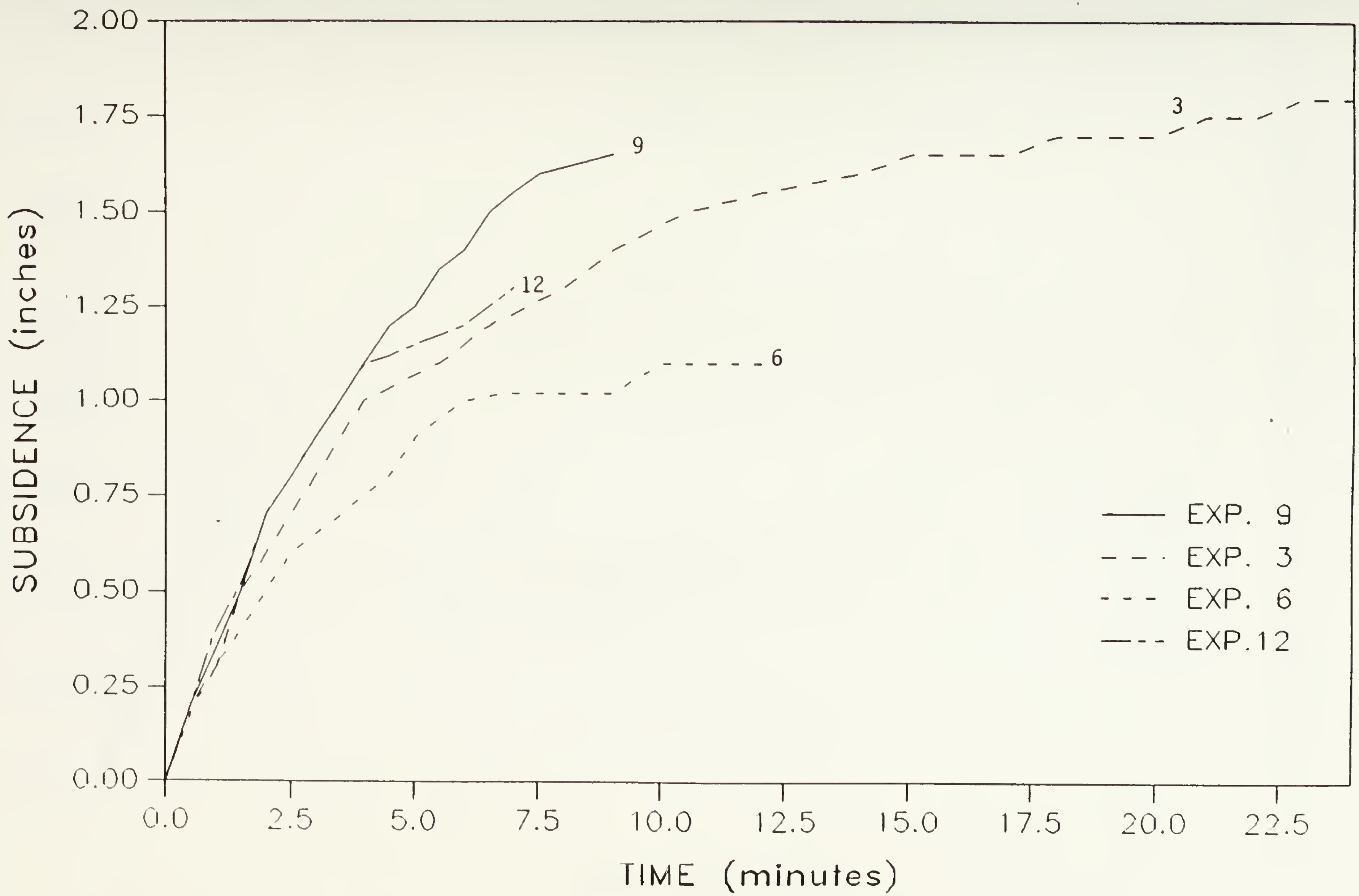


FIGURE 28

Subsidence vs. Time

Subsidence vs Time

T = 10 secs; Experiments 8,1,11,& 5

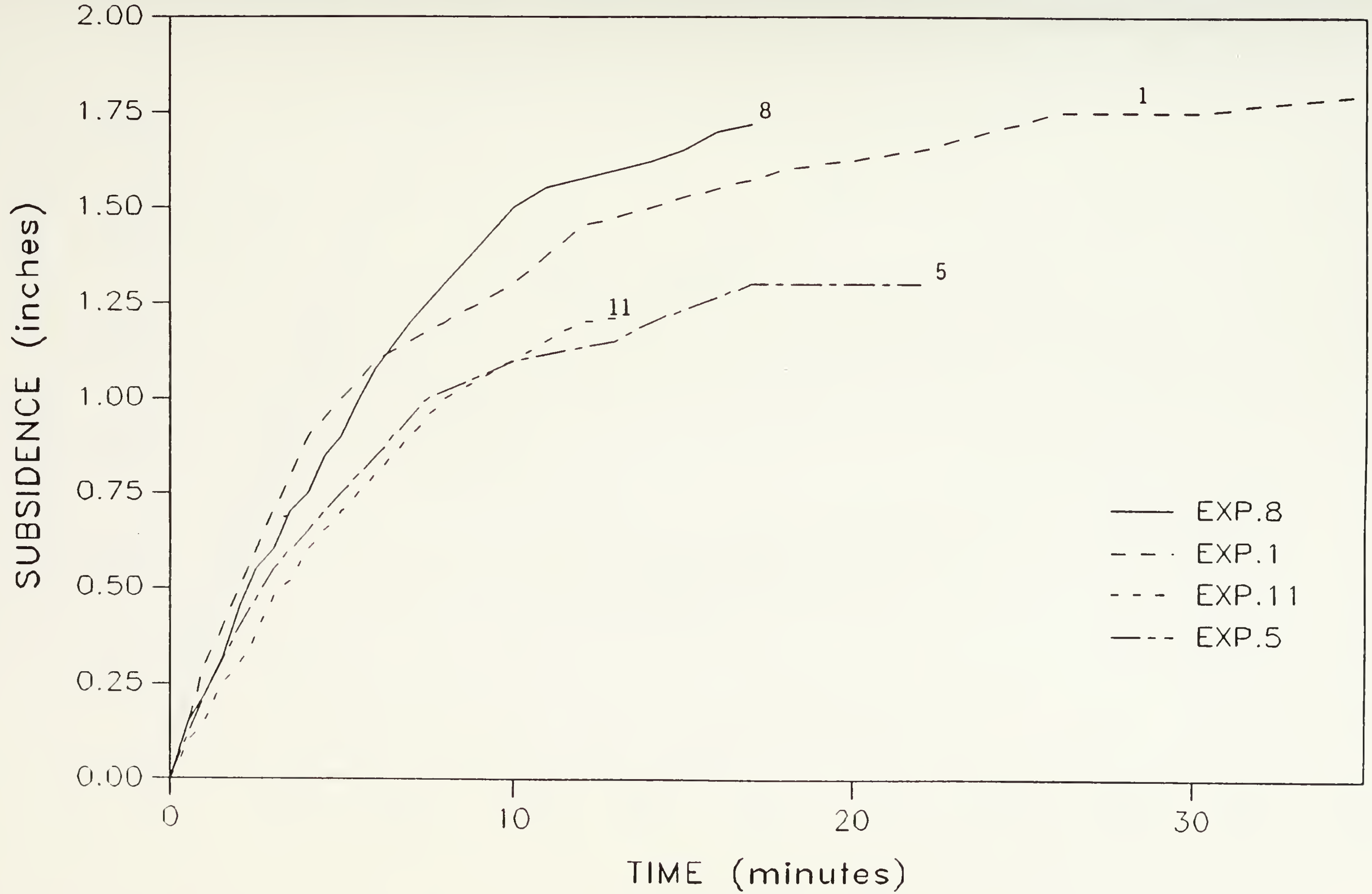


FIGURE 29

Subsidence vs Time

T = 20 secs; Experiments 7,4,10,& 2

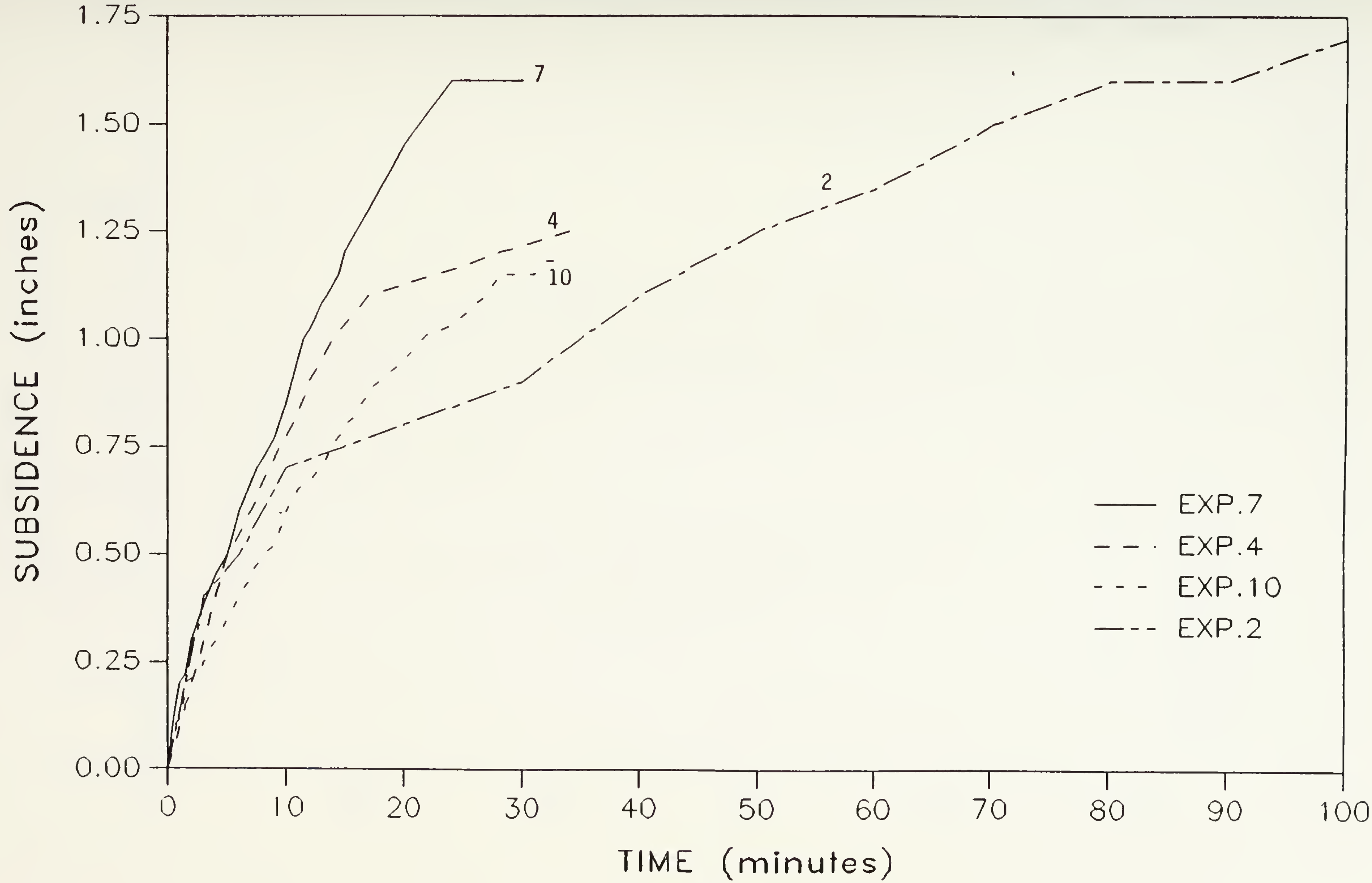


FIGURE 30

Subsidence vs Cycle

Experiments 1,2,3,4,5,& 6

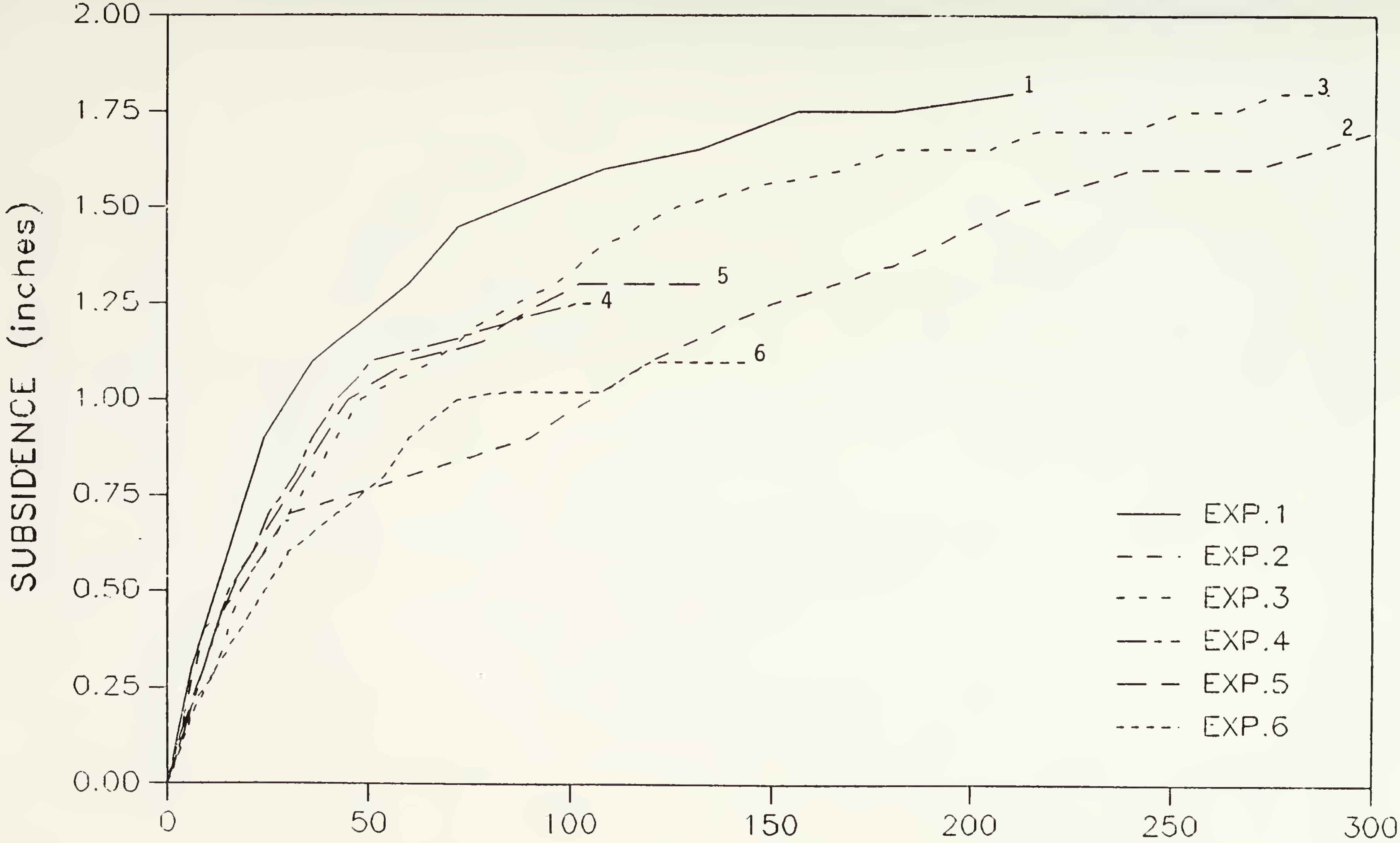


FIGURE 31

Subsidence vs Cycles

Experiments 7,8,9,10,11,& 12

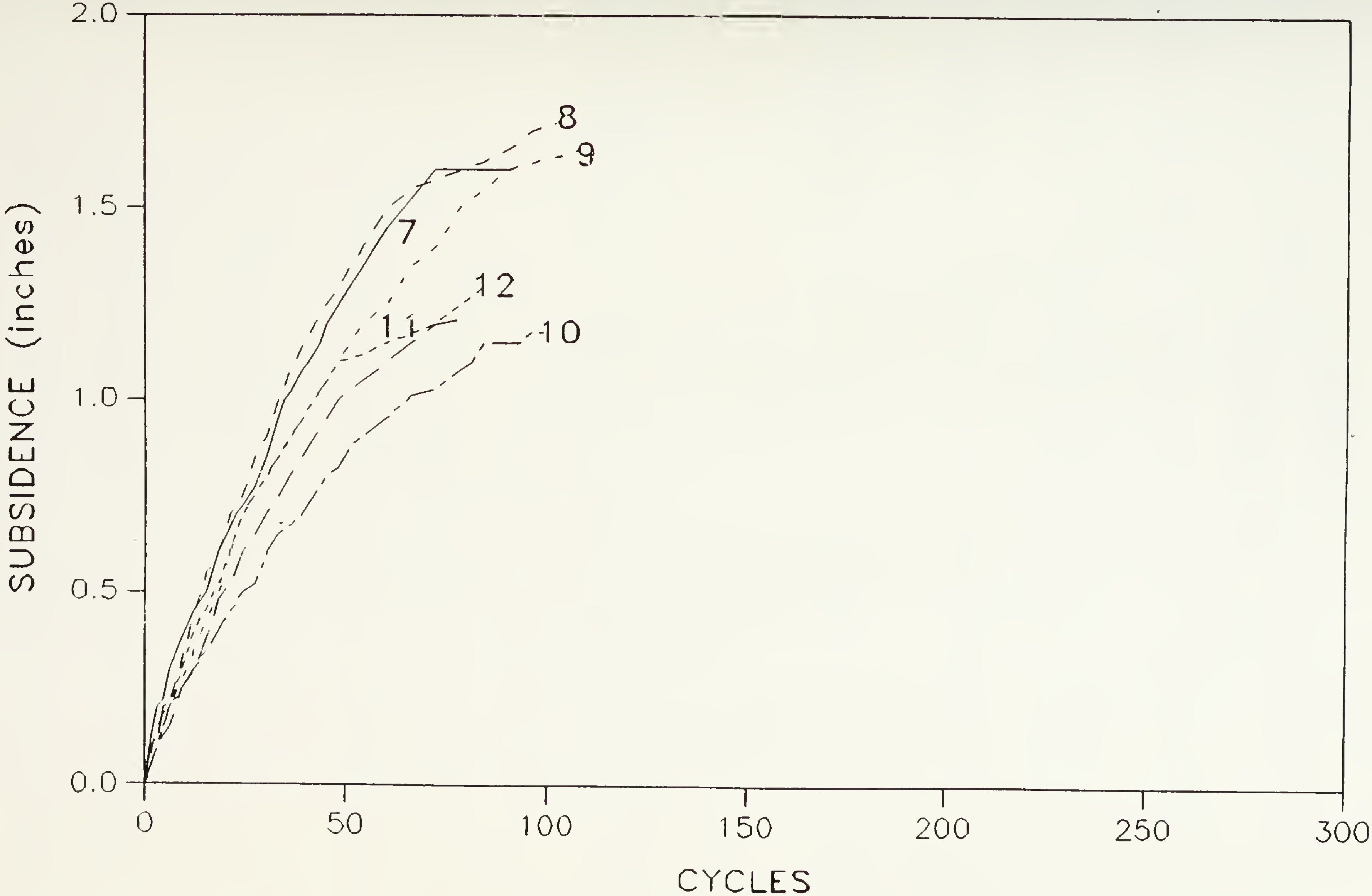


FIGURE 32

APPENDIX B

EXPERIMENTAL DATA

1	0.00	10	1.0	1	25	0.042	3.3	0.000009558	0.0	0.00000	0.0000	0.00000	0.000000	0.00000	0.00000
2	0.00	20	1.0	1	25	0.042	3.3	0.000008572	0.0	0.00000	0.0000	0.00000	0.000000	0.00000	0.00000
3	0.00	5	1.0	1	25	0.042	3.3	0.000008572	0.0	0.00000	0.0000	0.00000	0.000000	0.00000	0.00000
4	0.00	20	0.8	1	25	0.042	3.3	0.000008572	0.0	0.00000	0.0000	0.00000	0.000000	0.00000	0.00000
5	0.00	10	0.8	1	25	0.042	3.3	0.000008572	0.0	0.00000	0.0000	0.00000	0.000000	0.00000	0.00000
6	0.00	5	0.8	1	25	0.011	3.3	0.000008572	0.0	0.00000	0.0000	0.00000	0.000000	0.00000	0.00000
7	0.00	20	1.0	2	36	0.011	3.3	0.000008572	0.0	0.00000	0.0000	0.00000	0.000000	0.00000	0.00000
8	0.00	10	1.0	2	36	0.011	3.3	0.000008572	0.0	0.00000	0.0000	0.00000	0.000000	0.00000	0.00000
9	0.00	5	1.0	2	36	0.011	3.3	0.000008572	0.0	0.00000	0.0000	0.00000	NODATA	0.00000	0.00000
10	0.00	20	0.8	2	36	0.011	3.3	0.000008572	0.0	0.00000	0.0000	0.00000	NODATA	0.00000	0.00000
11	0.00	10	0.8	2	36	0.011	3.3	0.000008572	0.0	0.00000	0.0000	0.00000	NODATA	0.00000	0.00000
12	0.00	5	0.8	2	36	0.011	3.3	0.000008572	0.0	0.00000	0.0000	0.00000	NODATA	0.00000	0.00000
13	0.05	20	0.8	1	25	0.042	3.3	0.000008572	1.5	-0.04300	4.1771	0.17200	2.900431	0.33062	0.70833
14	0.10	20	0.8	1	25	0.042	3.3	0.000008572	3.0	-0.04300	4.1771	0.19350	2.900431	0.28125	1.12500
15	0.10	20	0.8	2	36	0.011	3.3	0.000008572	1.5	-0.02150	2.0886	0.10750	NODATA	1.80000	2.25000
16	0.10	10	0.8	2	36	0.011	3.3	0.000008572	3.0	-0.06450	6.2657	0.15050	NODATA	1.80000	2.25000
17	0.12	10	0.8	1	25	0.042	3.3	0.000008572	3.0	-0.06450	6.2657	0.18275	1.160172	0.46000	2.30000
18	0.12	20	1.0	2	36	0.011	3.3	0.000008572	1.5	-0.03225	3.1329	0.10750	1.740258	0.46667	2.80000
19	0.12	20	0.8	2	36	0.011	3.3	0.000008572	3.0	-0.02580	2.5063	0.10750	NODATA	1.15000	2.30000
20	0.15	20	0.8	1	25	0.042	3.3	0.000008572	4.5	-0.04300	4.1771	0.19350	3.480517	0.29688	1.90000
21	0.15	10	1.0	2	36	0.011	3.3	0.000008572	3.0	-0.08600	8.3790	0.12900	1.160172	0.82143	3.83333
22	0.15	10	0.8	2	36	0.011	3.3	0.000008572	6.0	-0.06450	6.2657	0.15050	NODATA	1.18750	2.37500
23	0.18	5	0.8	1	25	0.011	3.3	0.000008572	6.0	-0.12900	12.5311	0.15050	0.000000	1.63333	2.45000
24	0.20	5	1.0	1	25	0.042	3.3	0.000008572	6.0	-0.08600	8.3540	0.15050	2.204328	1.20000	3.00000
25	0.20	20	0.8	1	25	0.042	3.3	0.000008572	6.0	-0.04300	4.1771	0.19350	3.480517	0.31250	2.00000
26	0.20	20	1.0	2	36	0.011	3.3	0.000008572	3.0	-0.03225	3.1329	0.12900	1.740258	0.46154	3.00000
27	0.20	5	1.0	2	36	0.011	3.3	0.000008572	6.0	-0.15050	14.6200	0.17200	NODATA	2.40000	3.00000
28	0.20	20	0.8	2	36	0.011	3.3	0.000008572	4.5	-0.03225	3.1329	0.10750	NODATA	1.25000	2.50000
29	0.20	5	0.8	2	36	0.011	3.3	0.000008572	6.0	-0.10750	10.4429	0.16125	NODATA	2.00000	2.50000
30	0.21	20	0.8	2	36	0.011	3.3	0.000008572	6.0	-0.03225	3.1329	0.10750	NODATA	1.26250	2.52500
31	0.22	10	0.8	1	25	0.042	3.3	0.000008572	6.0	-0.06450	6.2657	0.18275	9.281381	0.51000	2.55000
32	0.22	20	1.0	2	36	0.011	3.3	0.000008572	4.5	-0.03225	3.1329	0.12900	1.740258	0.43571	3.05000
33	0.22	10	1.0	2	36	0.011	3.3	0.000008572	6.0	-0.08600	8.3790	0.15050	1.160172	1.01667	2.44000
34	0.22	20	0.8	2	36	0.011	3.3	0.000008572	7.5	-0.03225	3.1329	0.10750	NODATA	1.27500	2.55000
35	0.25	20	0.8	2	36	0.011	3.3	0.000008572	9.0	-0.02472	2.4019	0.10750	NODATA	1.31250	2.62500
36	0.25	10	0.8	2	36	0.011	3.3	0.000008572	9.0	-0.05375	5.2214	0.13975	NODATA	1.31250	2.62500
37	0.30	10	1.0	1	25	0.042	3.3	0.000009558	6.0	-0.08600	8.3790	0.25800	1.144538	0.81250	3.25000
38	0.30	5	1.0	1	25	0.042	3.3	0.000008572	12.0	-0.10750	10.4425	0.17200	9.281381	1.30000	3.25000
39	0.30	20	0.8	1	25	0.042	3.3	0.000008572	9.0	-0.04300	4.1771	0.18275	2.900431	0.30556	2.20000
40	0.30	5	0.8	1	25	0.011	3.3	0.000008572	12.0	-0.10750	10.4425	0.16125	0.000000	1.10000	2.20000
41	0.30	20	1.0	2	36	0.011	3.3	0.000008572	6.0	-0.04300	4.1771	0.12900	1.624241	0.46429	3.25000
42	0.30	20	0.8	2	36	0.011	3.3	0.000008572	12.0	-0.03225	3.1329	0.11825	NODATA	1.37500	2.75000
43	0.30	10	0.8	2	36	0.011	3.3	0.000008572	12.0	-0.04945	4.8037	0.14620	NODATA	1.37500	2.75000
44	0.32	10	1.0	2	36	0.011	3.3	0.000008572	9.0	-0.08600	8.3790	0.16125	1.160172	1.65000	2.64000
45	0.35	5	1.0	2	36	0.011	3.3	0.000008572	12.0	-0.12900	12.5314	0.19350	NODATA	1.68750	3.37500
46	0.35	20	0.8	2	36	0.011	3.3	0.000008572	15.0	-0.03225	3.1329	0.12900	NODATA	1.43750	2.87500
47	0.38	20	1.0	2	36	0.011	3.3	0.000008572	9.0	-0.04300	4.1771	0.16125	1.508224	0.43125	3.45000
48	0.38	10	0.8	2	36	0.011	3.3	0.000008572	15.0	-0.04730	4.5949	0.14620	NODATA	1.47500	2.95000
49	0.40	20	1.0	1	25	0.042	3.3	0.000008572	9.0	-0.02795	2.7151	0.12900	4.640690	0.41176	2.33333
50	0.40	20	0.8	1	25	0.042	3.3	0.000008572	12.0	-0.04300	4.1771	0.18275	3.480517	0.33333	2.00000
51	0.40	10	0.8	1	25	0.042	3.3	0.000008572	12.0	-0.06450	6.2657	0.17200	9.281381	0.54545	3.00000
52	0.40	5	0.8	1	25	0.011	3.3	0.000008572	18.0	-0.08600	8.3540	0.15050	0.000000	1.00000	3.00000
53	0.40	20	0.8	2	36	0.011	3.3	0.000008572	18.0	-0.04300	4.1771	0.15050	NODATA	1.50000	3.00000
54	0.40	5	0.8	2	36	0.011	3.3	0.000008572	12.0	-0.09675	9.3986	0.15050	NODATA	1.50000	3.00000
55	0.45	20	1.0	2	36	0.011	3.3	0.000008572	12.0	-0.04300	4.1771	0.17200	1.508224	0.45313	3.62500

								VISC	CYCS	PPWS	LI	PPWP	VE		
56	0.45	10	1.0	2	36	0.011	3.3	0.000008572	12.0	-0.07525	7.3316	0.16125	9.281381	1.81250	2.90000
57	0.45	20	0.8	2	36	0.011	3.3	0.000008572	21.0	-0.02150	2.0886	0.16125	NODATA	1.56250	3.12500
58	0.48	10	0.8	2	36	0.011	3.3	0.000008572	18.0	-0.04730	4.5949	0.15265	NODATA	1.60000	3.20000
59	0.50	10	1.0	1	25	0.042	3.3	0.000009558	12.0	-0.08600	8.3790	0.27950	1.144538	0.68182	3.75000
60	0.50	20	1.0	1	25	0.042	3.3	0.000008572	18.0	-0.02795	2.7151	0.05805	3.190474	0.39474	2.14286
61	0.50	5	1.0	1	25	0.042	3.3	0.000008572	18.0	-0.10750	10.4425	0.12900	9.281381	1.50000	3.75000
62	0.50	20	0.8	1	25	0.042	3.3	0.000008572	15.0	-0.04300	4.1771	0.17200	2.900431	0.32500	2.60000
63	0.50	5	0.8	1	25	0.011	3.3	0.000008572	24.0	-0.08600	8.3540	0.15050	0.000000	1.00000	3.25000
64	0.50	20	1.0	2	36	0.011	3.3	0.000008572	15.0	-0.04300	4.1771	0.17200	1.624241	0.46875	3.75000
65	0.50	5	1.0	2	36	0.011	3.3	0.000008572	18.0	-0.12900	12.5314	0.18275	NODATA	1.87500	3.75000
66	0.50	20	0.8	2	36	0.011	3.3	0.000008572	24.0	-0.02580	2.5063	0.17200	NODATA	1.62500	2.16667
67	0.52	20	0.8	2	36	0.011	3.3	0.000008572	27.0	-0.02580	2.5063	0.17200	NODATA	1.32000	2.20000
68	0.52	10	0.8	2	36	0.011	3.3	0.000008572	21.0	-0.04730	4.5949	0.17200	NODATA	1.65000	3.30000
69	0.52	5	0.8	2	36	0.011	3.3	0.000008572	18.0	-0.10320	10.0252	0.15050	NODATA	1.65000	3.30000
70	0.55	10	0.8	1	25	0.042	3.3	0.000008572	18.0	-0.06450	6.2657	0.15050	6.961035	0.61364	3.37500
71	0.55	10	1.0	2	36	0.011	3.3	0.000008572	15.0	-0.08600	8.3790	0.17200	9.281381	0.96875	5.16667
72	0.60	5	1.0	1	25	0.042	3.3	0.000008572	24.0	-0.10750	10.4425	0.12900	2.320345	1.60000	4.00000
73	0.60	20	0.8	1	25	0.042	3.3	0.000008572	21.0	-0.04300	4.1771	0.16125	2.552379	0.33333	3.50000
74	0.60	5	0.8	1	25	0.011	3.3	0.000008572	30.0	-0.08600	8.3540	0.15050	0.000000	1.00000	3.50000
75	0.60	20	1.0	2	36	0.011	3.3	0.000008572	18.0	-0.04300	4.1771	0.18275	1.624241	0.50000	3.20000
76	0.60	10	1.0	2	36	0.011	3.3	0.000008572	18.0	-0.06450	6.2842	0.17200	9.281381	0.88889	4.00000
77	0.60	20	0.8	2	36	0.011	3.3	0.000008572	30.0	-0.02580	2.5063	0.17200	NODATA	1.40000	2.33333
78	0.60	10	0.8	2	36	0.011	3.3	0.000008572	24.0	-0.04730	4.5949	0.17415	NODATA	1.75000	3.50000
79	0.65	10	0.8	1	25	0.042	3.3	0.000008572	24.0	-0.08600	8.3543	0.15050	4.640690	0.65909	3.62500
80	0.65	20	0.8	2	36	0.011	3.3	0.000008572	33.0	-0.03225	3.1329	0.17200	NODATA	1.81250	2.41667
81	0.67	20	0.8	2	36	0.011	3.3	0.000008572	36.0	-0.03870	3.7594	0.16125	NODATA	1.47000	2.45000
82	0.70	10	1.0	1	25	0.042	3.3	0.000009558	18.0	-0.06450	6.2842	0.23650	1.144538	0.77273	4.25000
83	0.70	20	1.0	1	25	0.042	3.3	0.000008572	30.0	-0.02795	2.7151	0.05805	3.190474	0.42500	2.42857
84	0.70	20	0.8	1	25	0.042	3.3	0.000008572	25.5	-0.04300	4.1771	0.16125	2.552379	0.34091	3.75000
85	0.70	5	0.8	1	25	0.011	3.3	0.000008572	42.0	-0.09675	9.3983	0.16125	0.000000	0.83333	3.00000
86	0.70	20	1.0	2	36	0.011	3.3	0.000008572	22.5	-0.03225	3.1329	0.19350	1.624241	0.47222	4.25000
87	0.70	10	1.0	2	36	0.011	3.3	0.000008572	21.0	-0.06450	6.2842	0.17200	9.281381	1.41667	1.70000
88	0.70	5	1.0	2	36	0.011	3.3	0.000008572	24.0	-0.12900	12.5314	0.17200	NODATA	2.12500	4.25000
89	0.70	20	0.8	2	36	0.011	3.3	0.000008572	39.0	-0.04300	4.1771	0.15050	NODATA	1.87500	3.75000
90	0.70	10	0.8	2	36	0.011	3.3	0.000008572	30.0	-0.05375	5.2214	0.19350	NODATA	1.87500	3.75000
91	0.70	5	0.8	2	36	0.011	3.3	0.000008572	24.0	-0.10750	10.4429	0.17200	NODATA	1.87500	3.75000
92	0.72	20	1.0	2	36	0.011	3.3	0.000008572	24.0	-0.03225	3.1329	0.19350	1.392207	0.50588	4.30000
93	0.75	20	1.0	1	25	0.042	3.3	0.000008572	45.0	-0.02795	2.7151	0.05805	3.190474	0.46053	2.50000
94	0.75	10	0.8	1	25	0.042	3.3	0.000008572	30.0	-0.08600	8.3543	0.15050	4.640690	0.70455	3.87500
95	0.75	10	1.0	2	36	0.011	3.3	0.000008572	24.0	-0.06450	6.2842	0.17200	1.160172	1.75000	1.75000
96	0.75	20	0.8	2	36	0.011	3.3	0.000008572	42.0	-0.03225	3.1329	0.13975	NODATA	1.93750	3.87500
97	0.77	20	1.0	2	36	0.011	3.3	0.000008572	27.0	-0.03225	3.1329	0.17200	1.392207	0.52059	4.42500
98	0.80	20	1.0	1	25	0.042	3.3	0.000008572	60.0	-0.02795	2.7151	0.05805	3.190474	0.45000	2.57143
99	0.80	5	1.0	1	25	0.042	3.3	0.000008572	36.0	-0.08600	8.3540	0.12900	2.320345	1.80000	3.60000
100	0.80	20	0.8	1	25	0.042	3.3	0.000008572	31.5	-0.04300	4.1771	0.16125	2.552379	0.32000	4.00000
101	0.80	5	0.8	1	25	0.011	3.3	0.000008572	54.0	-0.09675	9.3983	0.16125	0.000000	1.14286	4.00000
102	0.80	5	1.0	2	36	0.011	3.3	0.000008572	30.0	-0.12900	12.5314	0.18275	NODATA	2.25000	4.50000
103	0.80	20	0.8	2	36	0.011	3.3	0.000008572	45.0	-0.03225	3.1329	0.13975	NODATA	2.00000	4.00000
104	0.80	10	0.8	2	36	0.011	3.3	0.000008572	36.0	-0.06020	5.8480	0.17200	NODATA	2.00000	4.00000
105	0.80	5	0.8	2	36	0.011	3.3	0.000008572	30.0	-0.08600	8.3543	0.16125	NODATA	2.00000	4.00000
106	0.82	20	0.8	2	36	0.011	3.3	0.000008572	48.0	-0.03225	3.1329	0.12900	NODATA	2.02500	4.05000
107	0.85	20	1.0	1	25	0.042	3.3	0.000008572	75.0	-0.02795	2.7151	0.04300	3.190474	0.46250	2.64286
108	0.85	10	0.8	1	25	0.042	3.3	0.000008572	36.0	-0.08600	8.3543	0.15050	4.640690	0.68750	4.12500
109	0.85	20	1.0	2	36	0.011	3.3	0.000008572	30.0	-0.03225	3.1329	0.17200	1.392207	0.51389	4.62500
110	0.85	10	1.0	2	36	0.011	3.3	0.000008572	27.0	-0.06450	6.2842	0.16125	2.320345	1.02778	4.62500

OBS	SUBSID	T	A	AP	W	TH	BRHO	VISC	CYCS	PPWS	LI	PPWP	VE	VPU	VPD
111	0.88	20	0.8	2	36	0.011	3.3	0.000008572	51.0	-0.03225	3.1329	0.12900	NODATA	2.10000	4.20000
112	0.90	10	1.0	1	25	0.042	3.3	0.000009558	24.0	-0.08600	8.3790	0.22575	1.144538	0.86364	4.75000
113	0.90	20	1.0	1	25	0.042	3.3	0.000008572	90.0	-0.02795	2.7151	0.04300	3.190474	0.50000	2.37500
114	0.90	5	1.0	1	25	0.042	3.3	0.000008572	42.0	-0.08600	8.3540	0.12900	2.320345	1.90000	3.80000
115	0.90	20	0.8	1	25	0.042	3.3	0.000008572	36.0	-0.04300	4.1771	0.16125	2.552379	0.34000	4.25000
116	0.90	5	0.8	1	25	0.011	3.3	0.000008572	60.0	-0.08600	8.3540	0.15050	0.000000	1.06250	3.40000
117	0.90	10	1.0	2	36	0.011	3.3	0.000008572	30.0	-0.06450	6.2842	0.15050	1.160172	1.35714	2.37500
118	0.90	5	1.0	2	36	0.011	3.3	0.000008572	36.0	-0.12900	12.5314	0.17200	NODATA	2.37500	4.75000
119	0.90	20	0.8	2	36	0.011	3.3	0.000008572	54.0	-0.03225	3.1329	0.10750	NODATA	2.12500	4.25000
120	0.90	10	0.8	2	36	0.011	3.3	0.000008572	42.0	-0.05375	5.2214	0.15695	NODATA	2.12500	2.83333
121	0.90	5	0.8	2	36	0.011	3.3	0.000008572	36.0	-0.08600	8.3543	0.16125	NODATA	2.12500	4.25000
122	0.95	20	1.0	2	36	0.011	3.3	0.000008572	33.0	-0.02150	2.0886	0.16125	1.392207	0.54167	4.87500
123	0.95	20	0.8	2	36	0.011	3.3	0.000008572	60.0	-0.04300	4.1771	0.10750	NODATA	2.18750	4.37500
124	1.00	10	1.0	1	25	0.042	3.3	0.000009558	30.0	-0.07525	7.3316	0.21500	1.248587	0.76923	4.00000
125	1.00	20	1.0	1	25	0.042	3.3	0.000008572	105.0	-0.02795	2.7151	0.07955	3.480517	0.52632	2.85714
126	1.00	5	1.0	1	25	0.042	3.3	0.000008572	48.0	-0.10750	10.4425	0.13975	2.320345	2.00000	3.33333
127	1.00	20	0.8	1	25	0.042	3.3	0.000008572	42.0	-0.04300	4.1771	0.17200	2.552379	0.34615	4.50000
128	1.00	10	0.8	1	25	0.042	3.3	0.000008572	45.0	-0.08600	8.3543	0.15050	4.640690	0.75000	4.50000
129	1.00	5	0.8	1	25	0.011	3.3	0.000008572	72.0	-0.10750	10.4425	0.17200	0.000000	1.12500	4.50000
130	1.00	20	1.0	2	36	0.011	3.3	0.000008572	34.5	-0.02150	2.0886	0.15050	1.392207	0.55556	5.00000
131	1.00	10	1.0	2	36	0.011	3.3	0.000008572	33.0	-0.06450	6.2842	0.15050	2.320345	1.42857	2.50000
132	1.00	5	1.0	2	36	0.011	3.3	0.000008572	42.0	-0.12900	12.5314	0.15050	NODATA	2.50000	5.00000
133	1.00	10	0.8	2	36	0.011	3.3	0.000008572	48.0	-0.04300	4.1771	0.12900	NODATA	1.80000	3.00000
134	1.00	5	0.8	2	36	0.011	3.3	0.000008572	42.0	-0.08600	8.3543	0.16125	NODATA	2.25000	4.50000
135	1.01	20	0.8	2	36	0.011	3.3	0.000008572	66.0	-0.04300	4.1771	0.10750	NODATA	2.26250	4.52500
136	1.02	5	0.8	1	25	0.011	3.3	0.000008572	84.0	-0.08600	8.3540	0.08600	0.000000	1.13750	2.27500
137	1.02	5	0.8	1	25	0.011	3.3	0.000008572	96.0	-0.08600	8.3540	0.09675	0.000000	0.91000	2.27500
138	1.02	5	0.8	1	25	0.011	3.3	0.000008572	108.0	-0.08600	8.3540	0.09675	0.000000	1.13750	2.27500
139	1.02	20	1.0	2	36	0.011	3.3	0.000008572	36.0	-0.02150	2.0886	0.13975	1.392207	0.56111	5.05000
140	1.03	20	0.8	2	36	0.011	3.3	0.000008572	72.0	-0.03225	3.1329	0.12900	NODATA	2.28750	4.57500
141	1.05	20	1.0	2	36	0.011	3.3	0.000008572	37.5	-0.02150	2.0886	0.12900	1.392207	0.56944	5.12500
142	1.05	10	0.8	2	36	0.011	3.3	0.000008572	54.0	-0.04300	4.1771	0.10750	NODATA	1.85000	3.08333
143	1.08	20	1.0	2	36	0.011	3.3	0.000008572	39.0	-0.02150	2.0886	0.12900	1.392207	0.57778	5.20000
144	1.08	10	1.0	2	36	0.011	3.3	0.000008572	36.0	-0.06450	6.2842	0.15050	2.320345	1.15556	4.16000
145	1.08	20	0.8	2	36	0.011	3.3	0.000008572	78.0	-0.04300	4.1771	0.10750	NODATA	2.35000	4.70000
146	1.10	10	1.0	1	25	0.042	3.3	0.000009558	36.0	-0.07525	7.3316	0.21500	1.248587	0.80769	4.20000
147	1.10	20	1.0	1	25	0.042	3.3	0.000008572	120.0	-0.02795	2.7151	0.07955	4.060604	0.55263	3.00000
148	1.10	5	1.0	1	25	0.042	3.3	0.000008572	66.0	-0.10750	10.4425	0.13975	2.320345	2.10000	3.50000
149	1.10	20	0.8	1	25	0.042	3.3	0.000008572	51.0	-0.04300	4.1771	0.16125	2.552379	0.33929	4.75000
150	1.10	10	0.8	1	25	0.042	3.3	0.000008572	60.0	-0.08600	8.3543	0.12900	1.160172	0.79167	3.80000
151	1.10	5	0.8	1	25	0.011	3.3	0.000008572	120.0	-0.08600	8.3540	0.10750	0.000000	1.58333	2.11111
152	1.10	5	0.8	1	25	0.011	3.3	0.000008572	144.0	-0.08600	8.3540	0.09675	0.000000	1.35714	4.75000
153	1.10	20	1.0	2	36	0.011	3.3	0.000008572	40.5	-0.02150	2.0886	0.12900	1.392207	0.58333	5.25000
154	1.10	5	1.0	2	36	0.011	3.3	0.000008572	48.0	-0.10750	10.4429	0.15050	NODATA	2.62500	5.25000
155	1.10	20	0.8	2	36	0.011	3.3	0.000008572	81.0	-0.04300	4.1771	0.11825	NODATA	2.37500	4.75000
156	1.10	10	0.8	2	36	0.011	3.3	0.000008572	60.0	-0.04300	4.1771	0.10750	NODATA	2.37500	3.16667
157	1.10	5	0.8	2	36	0.011	3.3	0.000008572	48.0	-0.08600	8.3543	0.15050	NODATA	2.37500	4.75000
158	1.12	20	0.8	2	36	0.011	3.3	0.000008572	90.0	-0.04300	4.1771	0.12900	NODATA	2.40000	4.80000
159	1.12	5	0.8	2	36	0.011	3.3	0.000008572	54.0	-0.08600	8.3543	0.15050	NODATA	2.40000	4.80000
160	1.15	10	1.0	1	25	0.042	3.3	0.000009558	42.0	-0.06450	6.2842	0.21500	1.300612	0.82692	3.58333
161	1.15	20	0.8	1	25	0.042	3.3	0.000008572	69.0	-0.04300	4.1771	0.10750	2.320345	0.34821	3.25000
162	1.15	10	0.8	1	25	0.042	3.3	0.000008572	78.0	-0.08600	8.3543	0.12900	1.160172	0.75000	3.90000
163	1.15	20	1.0	2	36	0.011	3.3	0.000008572	43.5	-0.02150	2.0886	0.11825	1.392207	0.59722	5.37500
164	1.15	20	0.8	2	36	0.011	3.3	0.000008572	84.0	-0.04300	4.1771	0.11825	NODATA	2.43750	4.87500
165	1.15	20	0.8	2	36	0.011	3.3	0.000008572	93.0	-0.04300	4.1771	0.10750	NODATA	2.43750	4.87500

OBS	SUBSID	I	A	AP	W	TH	BRHO	VISC	CYCS	PPWS	LI	PPWP	VE	VPU	VPD
166	1.15	10	0.8	2	36	0.011	3.3	0.000008572	66	-0.04300	4.1771	0.10965	NODATA	1.95000	3.25000
167	1.15	5	0.8	2	36	0.011	3.3	0.000008572	60	-0.07525	7.3100	0.16125	NODATA	2.43750	4.87500
168	1.18	20	0.8	2	36	0.011	3.3	0.000008572	96	-0.04300	4.1771	0.10750	NODATA	2.47500	4.95000
169	1.18	20	0.8	2	36	0.011	3.3	0.000008572	99	-0.04300	4.1771	0.12900	NODATA	2.47500	4.95000
170	1.20	10	1.0	1	25	0.042	3.3	0.000009558	48	-0.06450	6.2842	0.15050	1.248587	0.78571	3.66667
171	1.20	5	1.0	1	25	0.042	3.3	0.000008572	78	-0.10750	10.4425	0.13975	2.320345	2.00000	3.66667
172	1.20	20	0.8	1	25	0.042	3.3	0.000008572	84	-0.04300	4.1771	0.10750	2.320345	0.34483	2.50000
173	1.20	10	0.8	1	25	0.042	3.3	0.000008572	84	-0.08600	8.3543	0.12900	1.160172	0.76923	3.33333
174	1.20	20	1.0	2	36	0.011	3.3	0.000008572	45	-0.02150	2.0886	0.11825	1.392207	0.61111	5.50000
175	1.20	10	1.0	2	36	0.011	3.3	0.000008572	42	-0.04300	4.1895	0.12900	2.320345	1.22222	2.75000
176	1.20	5	1.0	2	36	0.011	3.3	0.000008572	54	-0.10750	10.4429	0.15050	NODATA	2.75000	5.50000
177	1.20	10	0.8	2	36	0.011	3.3	0.000008572	72	-0.04300	4.1771	0.11825	NODATA	2.50000	5.00000
178	1.20	5	0.8	2	36	0.011	3.3	0.000008572	72	-0.09360	8.3543	0.15050	NODATA	2.50000	3.33333
179	1.21	10	0.8	2	36	0.011	3.3	0.000008572	78	-0.04300	4.1771	0.11825	NODATA	2.51250	5.02500
180	1.25	20	1.0	1	25	0.042	3.3	0.000008572	150	-0.03225	3.1328	0.07955	3.480517	0.56250	3.21429
181	1.25	20	0.8	1	25	0.042	3.3	0.000008572	102	-0.04300	4.1771	0.10750	2.320345	0.35345	2.56250
182	1.25	20	0.8	1	25	0.042	3.3	0.000008572	105	-0.04300	4.1771	0.10750	2.320345	0.35345	2.56250
183	1.25	20	1.0	2	36	0.011	3.3	0.000008572	48	-0.02150	2.0886	0.11825	1.392207	0.62500	5.62500
184	1.25	5	1.0	2	36	0.011	3.3	0.000008572	60	-0.10750	10.4429	0.15050	NODATA	2.81250	5.62500
185	1.30	10	1.0	1	25	0.042	3.3	0.000009558	60	-0.08600	8.3790	0.15050	1.040489	0.88462	3.83333
186	1.30	5	1.0	1	25	0.042	3.3	0.000008572	96	-0.10750	10.4425	0.13975	3.480517	2.09091	3.83333
187	1.30	10	0.8	1	25	0.042	3.3	0.000008572	102	-0.08600	8.3543	0.12900	1.160172	0.80769	3.50000
188	1.30	10	0.8	1	25	0.042	3.3	0.000008572	132	-0.06450	6.2657	0.08600	1.160172	0.75000	3.00000
189	1.30	20	1.0	2	36	0.011	3.3	0.000008572	51	-0.02150	2.0886	0.12900	1.392207	0.63889	5.75000
190	1.30	10	1.0	2	36	0.011	3.3	0.000008572	48	-0.04300	4.1895	0.11825	2.320345	1.15000	2.87500
191	1.30	5	0.8	2	36	0.011	3.3	0.000008572	84	-0.07525	7.3100	0.15050	NODATA	2.10000	3.50000
192	1.35	20	1.0	1	25	0.042	3.3	0.000008572	180	-0.04945	4.8036	0.05375	3.480517	0.58750	3.35714
193	1.35	20	1.0	2	36	0.011	3.3	0.000008572	54	-0.02150	2.0886	0.12900	1.392207	0.65278	5.87500
194	1.35	5	1.0	2	36	0.011	3.3	0.000008572	66	-0.12900	12.5314	0.16125	NODATA	2.93750	3.91667
195	1.40	5	1.0	1	25	0.042	3.3	0.000008572	108	-0.10750	10.4425	0.15050	2.320345	2.18182	4.00000
196	1.40	20	1.0	2	36	0.011	3.3	0.000008572	57	-0.02150	2.0886	0.12900	1.624241	0.66667	6.00000
197	1.40	10	1.0	2	36	0.011	3.3	0.000008572	54	-0.05375	5.2369	0.11825	2.320345	1.50000	2.40000
198	1.40	5	1.0	2	36	0.011	3.3	0.000008572	72	-0.11825	11.4872	0.15050	NODATA	2.40000	4.00000
199	1.45	10	1.0	1	25	0.042	3.3	0.000009558	72	-0.08600	8.3790	0.15050	1.040489	0.90741	4.08333
200	1.45	20	1.0	2	36	0.011	3.3	0.000008572	60	-0.02150	2.0886	0.12900	1.624241	0.64474	6.12500
201	1.50	10	1.0	1	25	0.042	3.3	0.000009558	84	-0.08600	8.3790	0.15050	1.040489	0.92593	4.16667
202	1.50	20	1.0	1	25	0.042	3.3	0.000008572	210	-0.04945	4.8036	0.05375	4.060604	0.59524	3.57143
203	1.50	5	1.0	1	25	0.042	3.3	0.000008572	126	-0.10750	10.4425	0.15050	2.320345	2.27273	4.16667
204	1.50	10	1.0	2	36	0.011	3.3	0.000008572	60	-0.04300	4.1895	0.11825	2.320345	1.13636	2.50000
205	1.50	5	1.0	2	36	0.011	3.3	0.000008572	78	-0.11825	11.4872	0.15050	NODATA	2.50000	4.16667
206	1.55	5	1.0	1	25	0.042	3.3	0.000008572	144	-0.10750	10.4425	0.15050	2.320345	2.12500	4.25000
207	1.55	10	1.0	2	36	0.011	3.3	0.000008572	66	-0.04300	4.1895	0.10750	2.320345	0.98077	3.18750
208	1.55	5	1.0	2	36	0.011	3.3	0.000008572	84	-0.10750	10.4429	0.15050	NODATA	3.18750	4.25000
209	1.60	10	1.0	1	25	0.042	3.3	0.000009558	108	-0.08600	8.3790	0.15050	1.040489	0.92857	4.33333
210	1.60	20	1.0	1	25	0.042	3.3	0.000008572	240	-0.04945	4.8036	0.06450	3.480517	0.56522	3.71429
211	1.60	20	1.0	1	25	0.042	3.3	0.000008572	270	-0.02795	2.7151	0.04300	3.248483	0.56522	3.71429
212	1.60	5	1.0	1	25	0.042	3.3	0.000008572	168	-0.10750	10.4425	0.10750	2.320345	2.16667	4.33333
213	1.60	20	1.0	2	36	0.011	3.3	0.000008572	72	-0.02150	2.0886	0.08600	1.624241	0.65000	2.60000
214	1.60	20	1.0	2	36	0.011	3.3	0.000008572	90	-0.02150	2.0886	0.06450	1.624241	1.00000	4.33333
215	1.60	5	1.0	2	36	0.011	3.3	0.000008572	90	-0.10750	10.4429	0.15050	NODATA	2.60000	4.33333
216	1.62	10	1.0	2	36	0.011	3.3	0.000008572	84	-0.04300	4.1895	0.12900	2.320345	1.19091	3.27500
217	1.65	10	1.0	1	25	0.042	3.3	0.000009558	132	-0.08600	8.3790	0.15050	1.040489	0.94643	4.41667
218	1.65	5	1.0	1	25	0.042	3.3	0.000008572	180	-0.10750	10.4425	0.10750	2.320345	2.20833	4.41667
219	1.65	5	1.0	1	25	0.042	3.3	0.000008572	204	-0.08600	8.3540	0.08600	1.160172	1.89286	4.41667
220	1.65	10	1.0	2	36	0.011	3.3	0.000008572	90	-0.04300	4.1895	0.12900	2.320345	1.47222	3.30000

221	1.65	5	1	2	36	0.011	3.3	0.000008572	108	-0.15050	14.6200	0.08600	NODATA	3.31250	6.62500
222	1.70	20	1	1	25	0.042	3.3	0.000008572	300	-0.04300	4.1770	0.08600	4.060604	0.54000	3.85714
223	1.70	20	1	1	25	0.042	3.3	0.000008572	330	-0.03225	3.1328	0.08600	4.408656	0.51923	3.85714
224	1.70	5	1	1	25	0.042	3.3	0.000008572	216	-0.08600	8.3540	0.08600	1.160172	1.92857	4.50000
225	1.70	5	1	1	25	0.042	3.3	0.000008572	240	-0.08600	8.3540	0.10750	1.160172	1.92857	4.50000
226	1.70	10	1	2	36	0.011	3.3	0.000008572	96	-0.04300	4.1895	0.11825	1.160172	1.03846	4.50000
227	1.72	10	1	2	36	0.011	3.3	0.000008572	102	-0.03225	3.1421	0.11825	2.320345	1.51111	3.40000
228	1.75	10	1	1	25	0.042	3.3	0.000009558	156	-0.08600	8.3790	0.12900	1.040489	0.98214	4.58333
229	1.75	10	1	1	25	0.042	3.3	0.000009558	180	-0.06450	6.2842	0.10750	UPDATE06	0.98214	3.43750
230	1.75	5	1	1	25	0.042	3.3	0.000008572	252	-0.08600	8.3540	0.10750	1.160172	1.96429	4.58333
231	1.75	5	1	1	25	0.042	3.3	0.000008572	264	-0.08600	8.3540	0.10750	1.160172	1.96429	4.58333
232	1.80	10	1	1	25	0.042	3.3	0.000009558	210	-0.10750	10.4737	0.12900	9.364406	0.93333	3.50000
233	1.80	5	1	1	25	0.042	3.3	0.000008572	276	-0.08600	8.3540	0.10750	1.160172	2.00000	4.66667
234	1.80	5	1	1	25	0.042	3.3	0.000008572	288	-0.08600	8.3540	0.10750	1.160172	2.00000	4.66667

APPENDIX C

SAND CONTOURS

SAND CONTOURS

EXPERIMENT 1

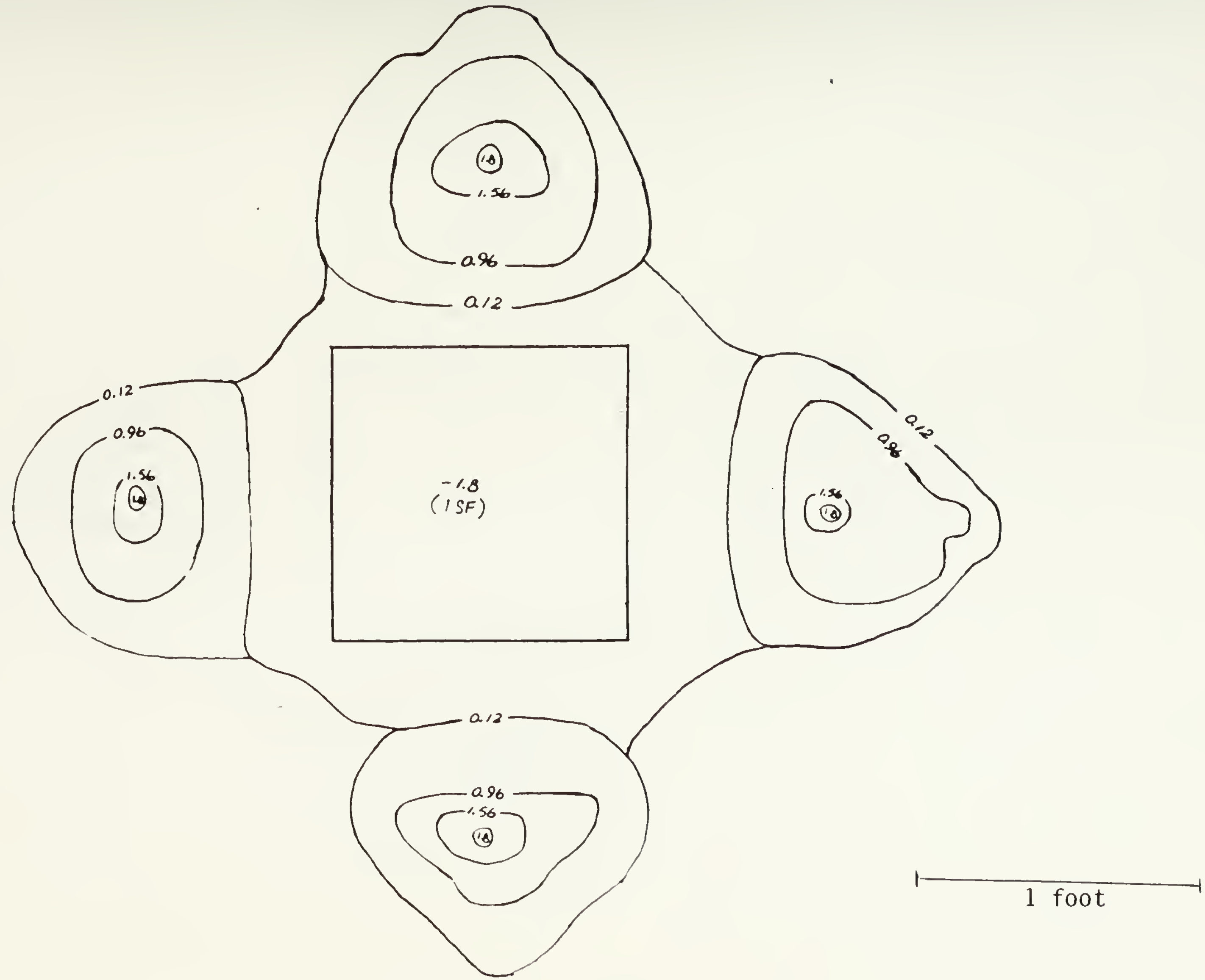


FIGURE C-1

SAND CONTOURS

EXPERIMENT 2

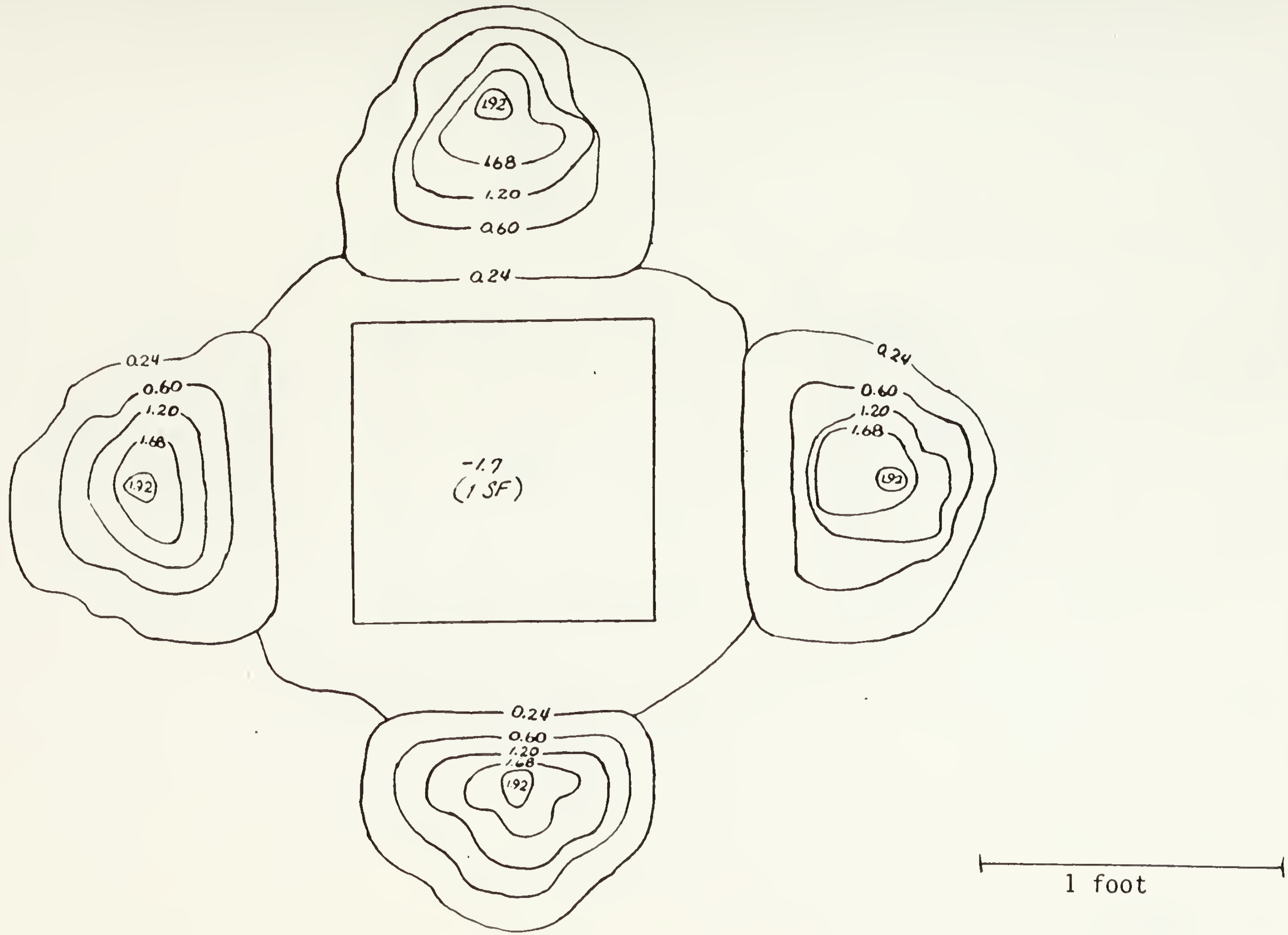


FIGURE C-2

SAND CONTOURS

SAND CONTOURS

EXPERIMENT 3

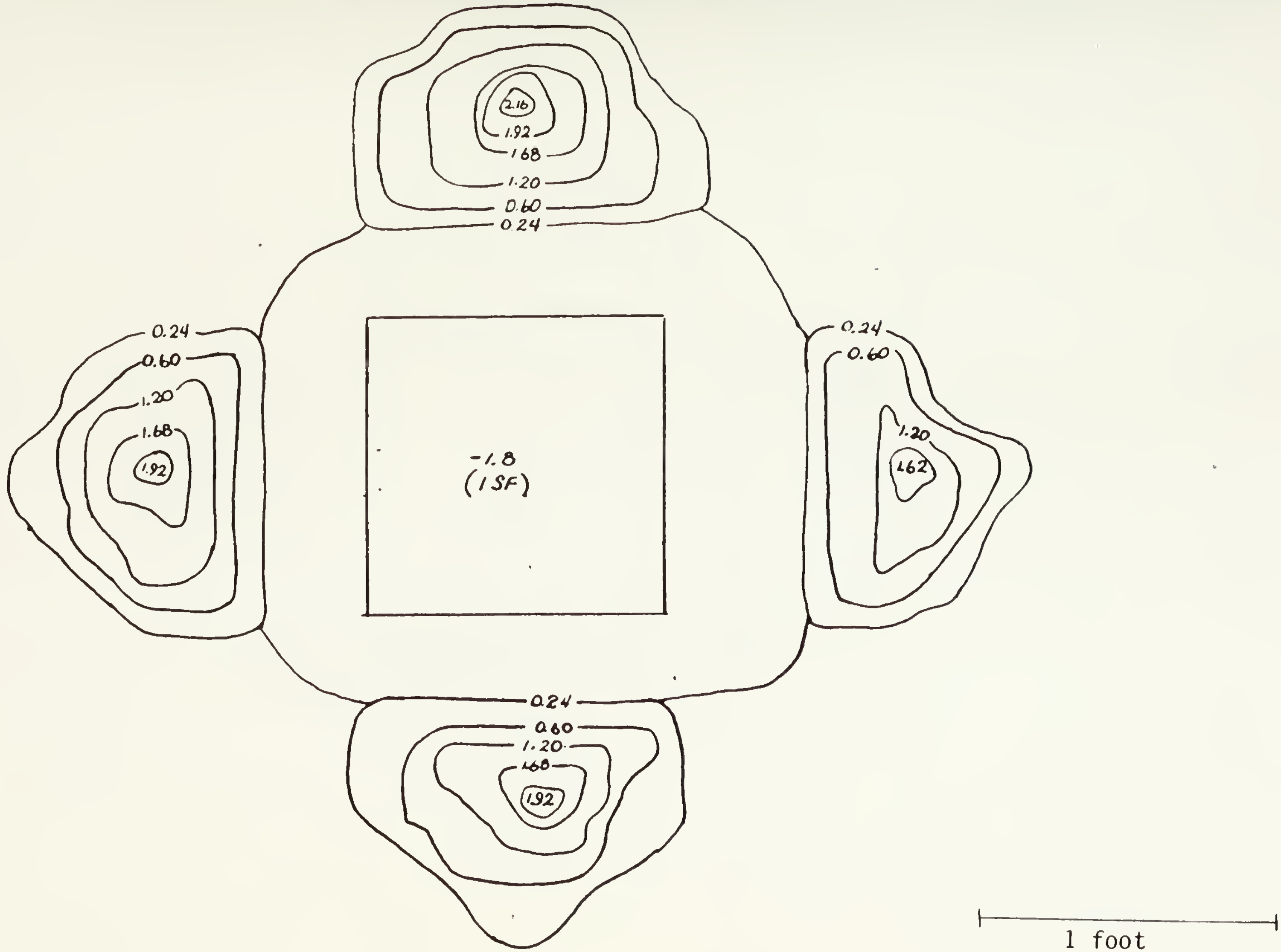


FIGURE C-3

SAND CONTOURS

EXPERIMENT 4

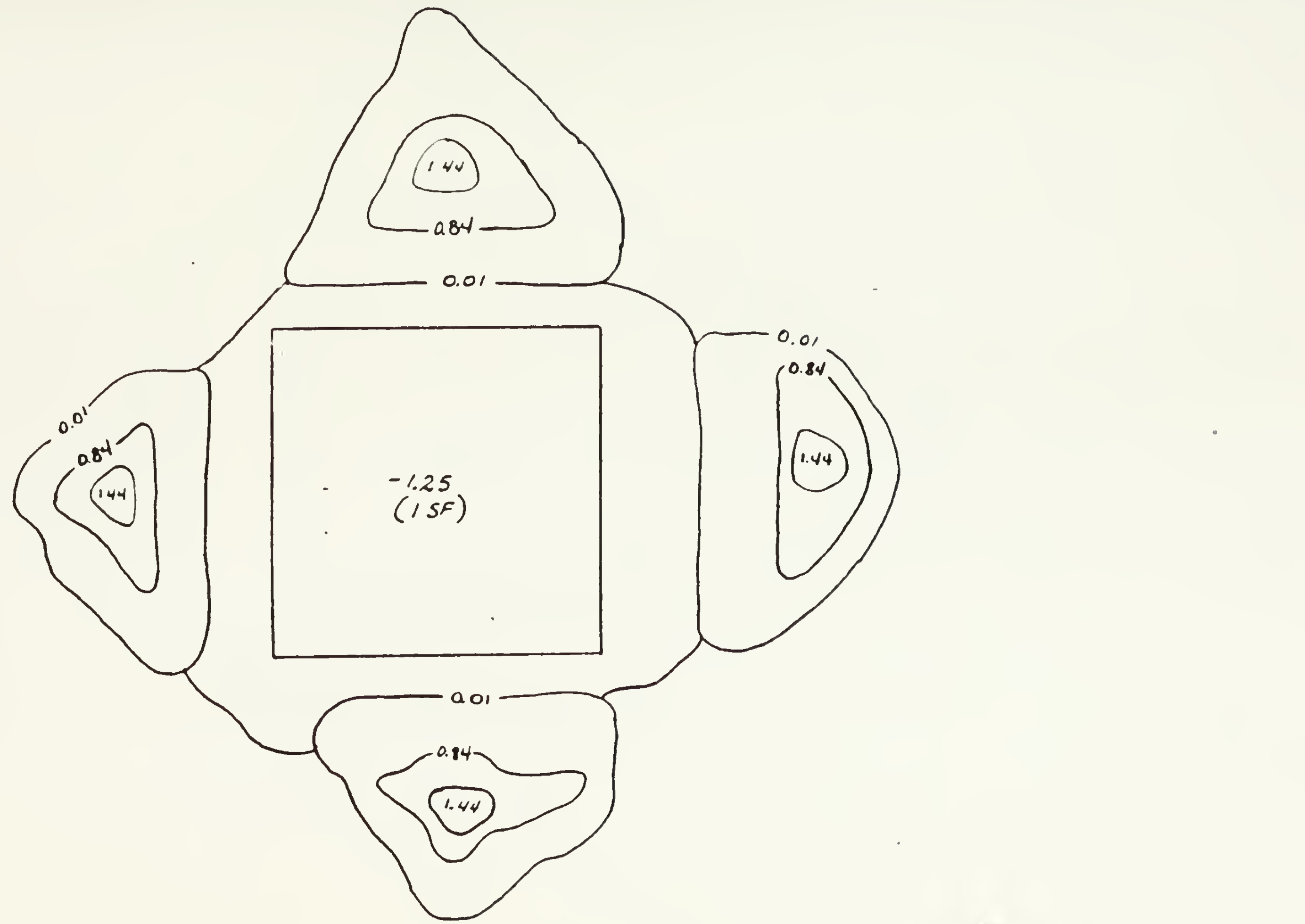


FIGURE C-4

SAND CONTOURS

EXPERIMENT 5

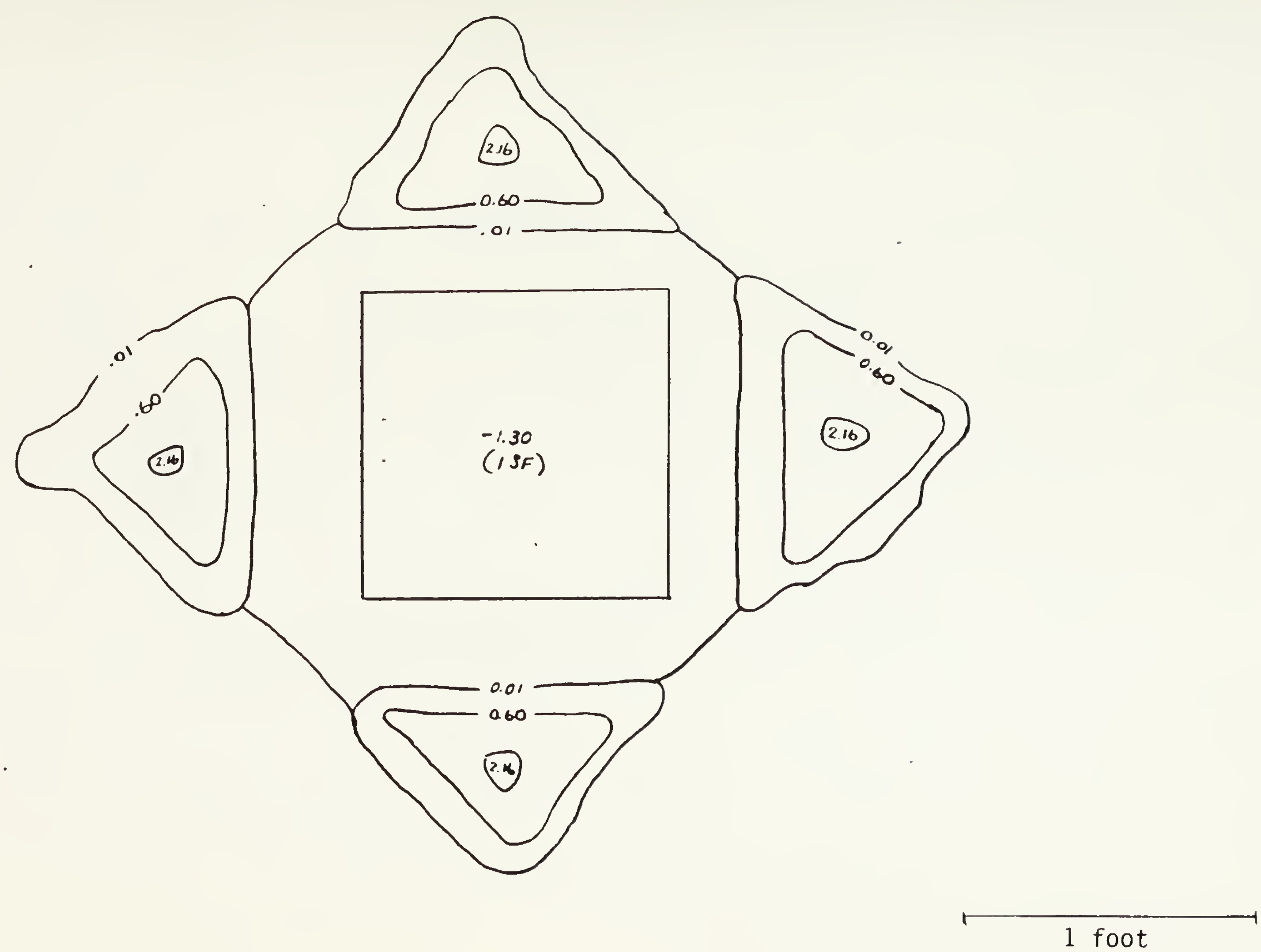


FIGURE C-5

SAND CONTOURS

EXPERIMENT 6

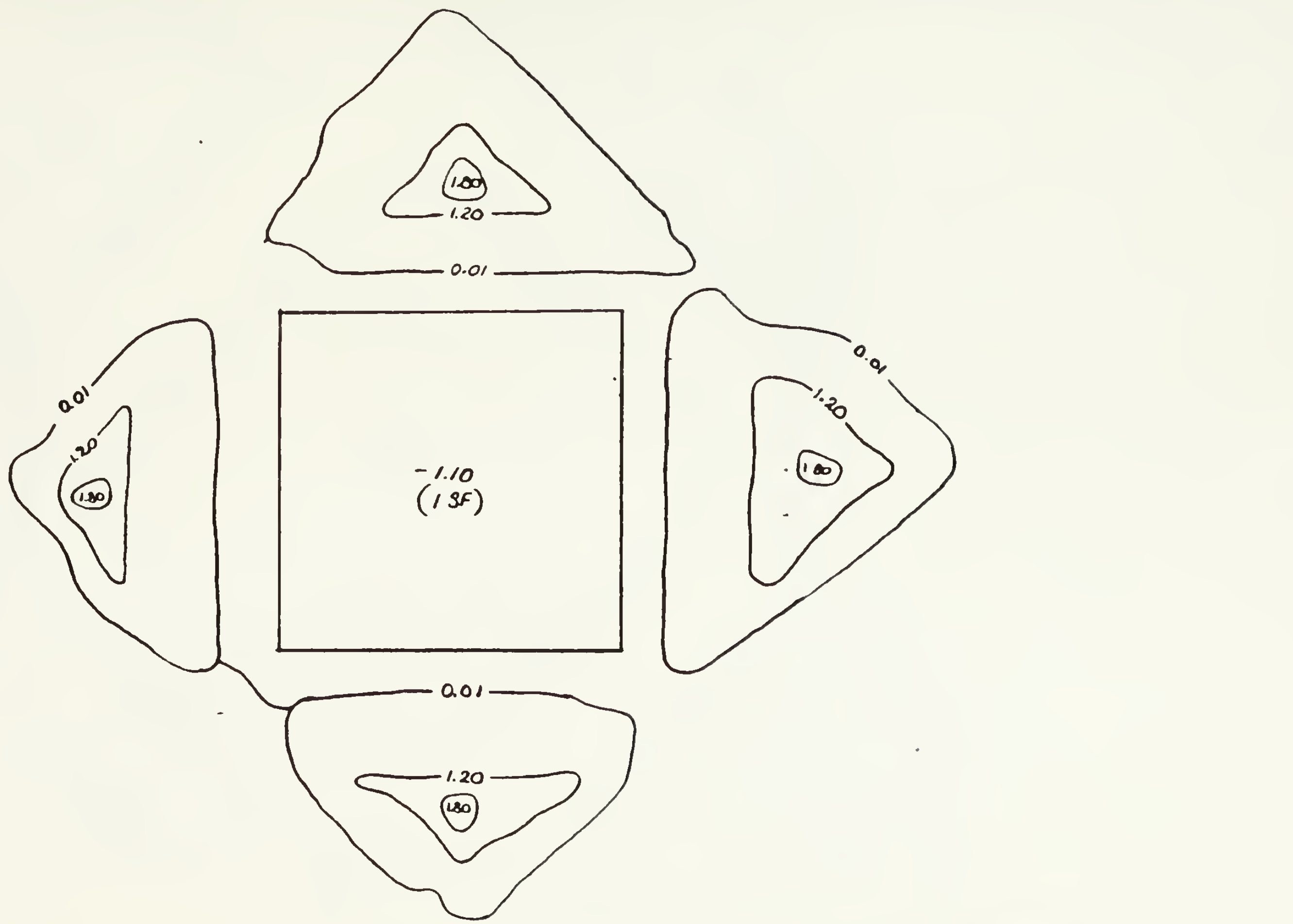


FIGURE C-6

SAND CONTOURS

EXPERIMENT 7

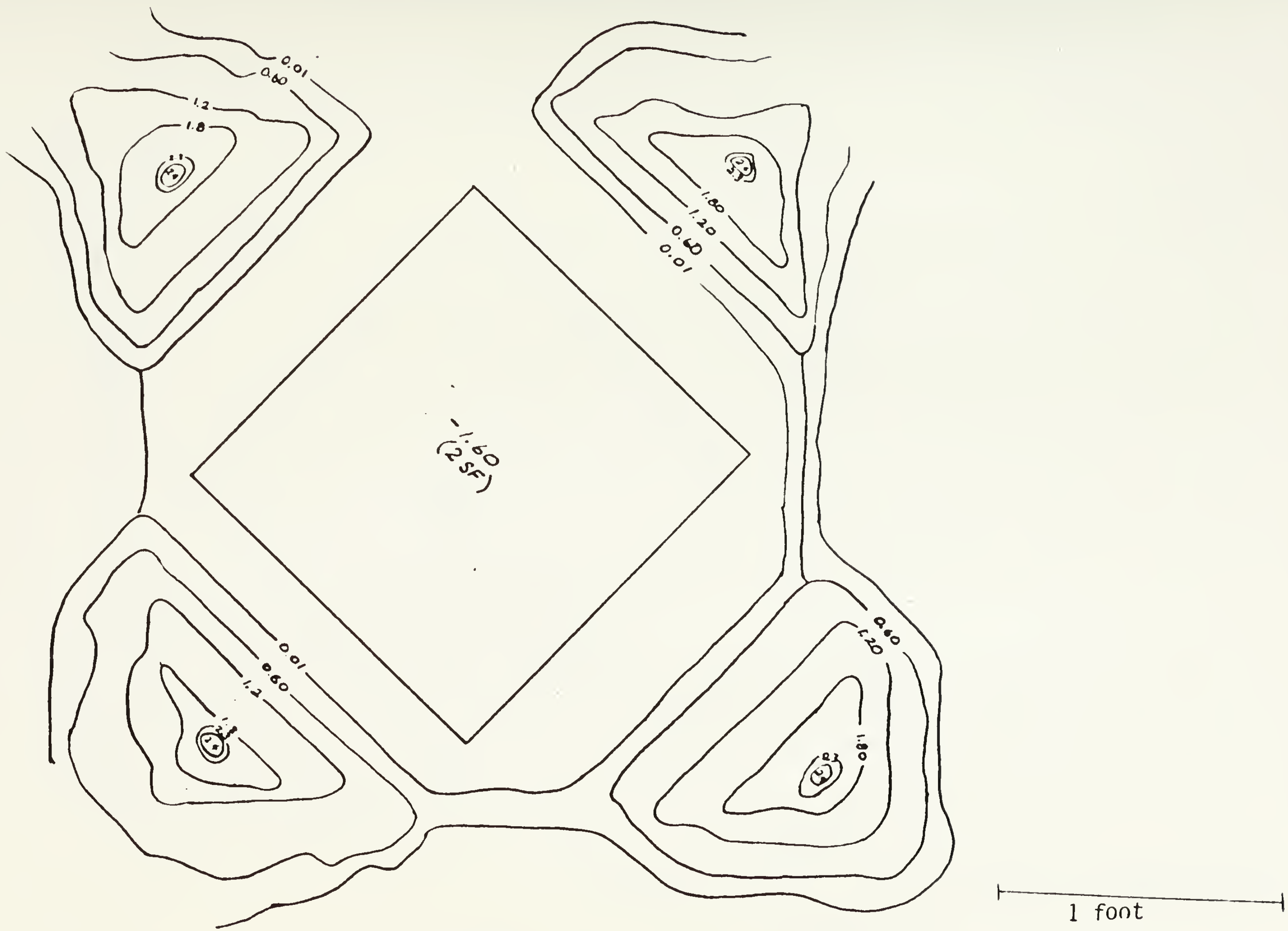


FIGURE C-7

SAND CONTOURS

EXPERIMENT 8

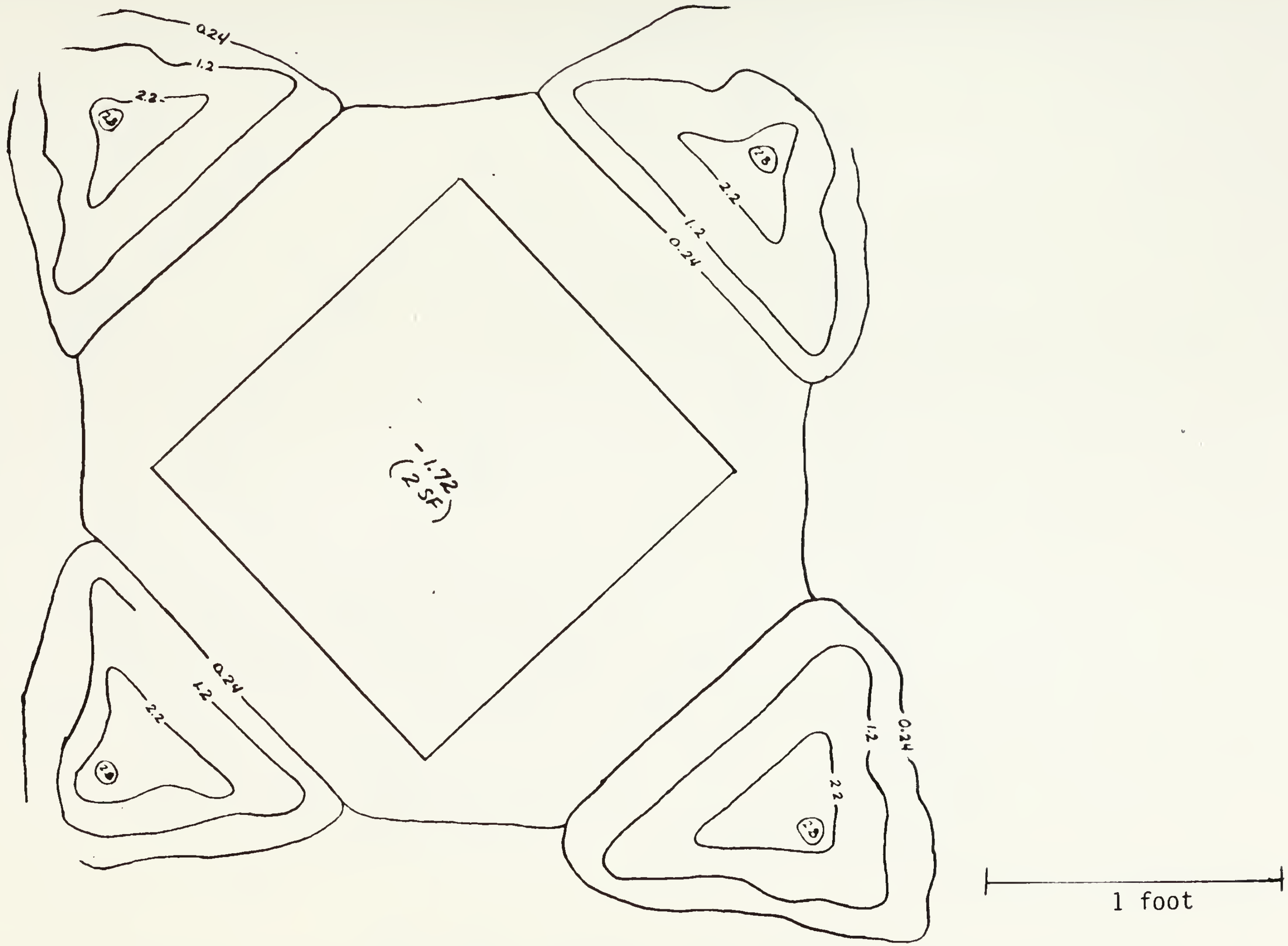


FIGURE C-8

SAND CONTOURS

EXPERIMENT 9

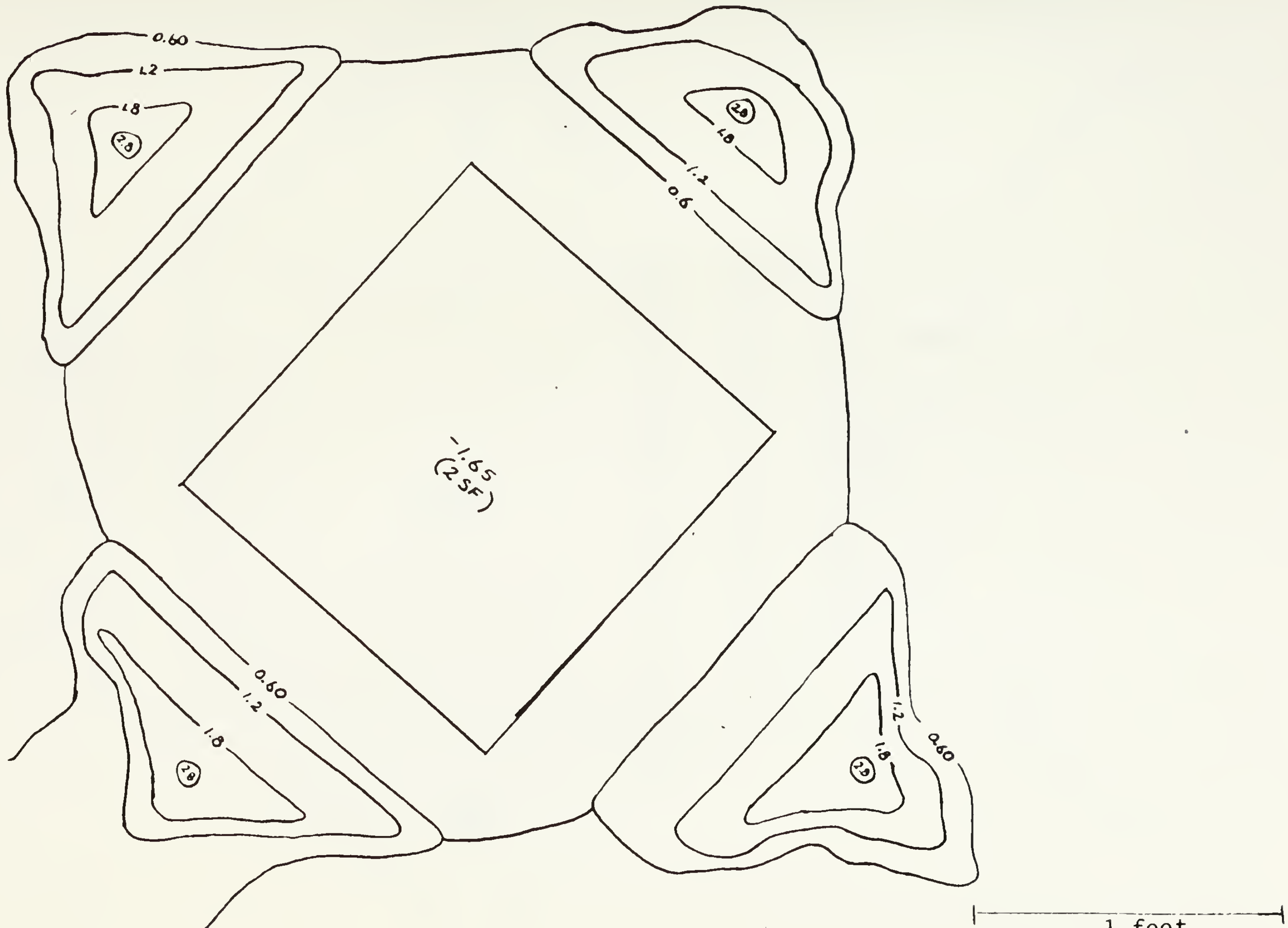


FIGURE C-9

SAND CONTOURS

EXPERIMENT 10

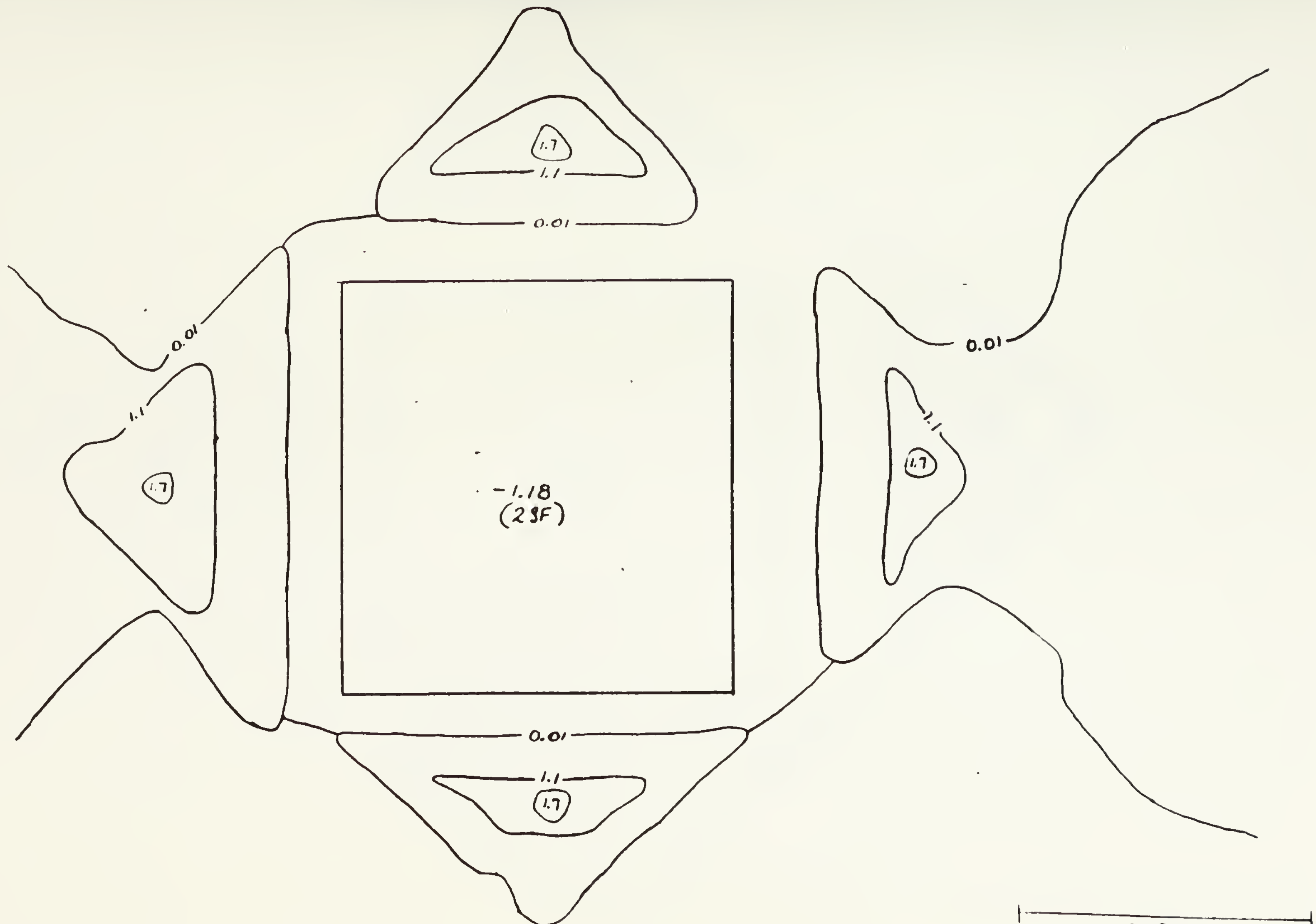


FIGURE C-10

SAND CONTOURS

EXPERIMENT 11

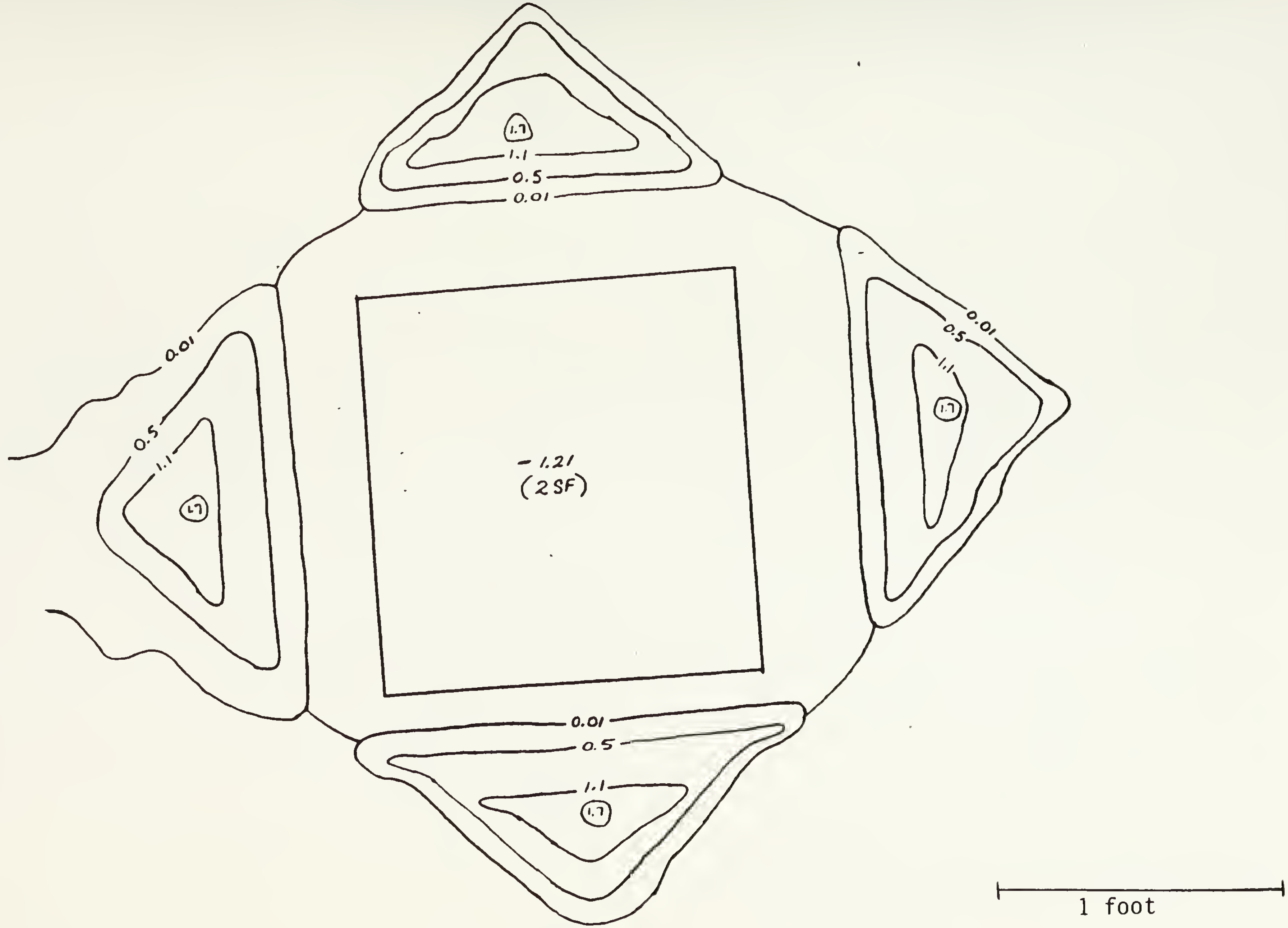


FIGURE C-11

SAND CONTOURS

EXPERIMENT 12

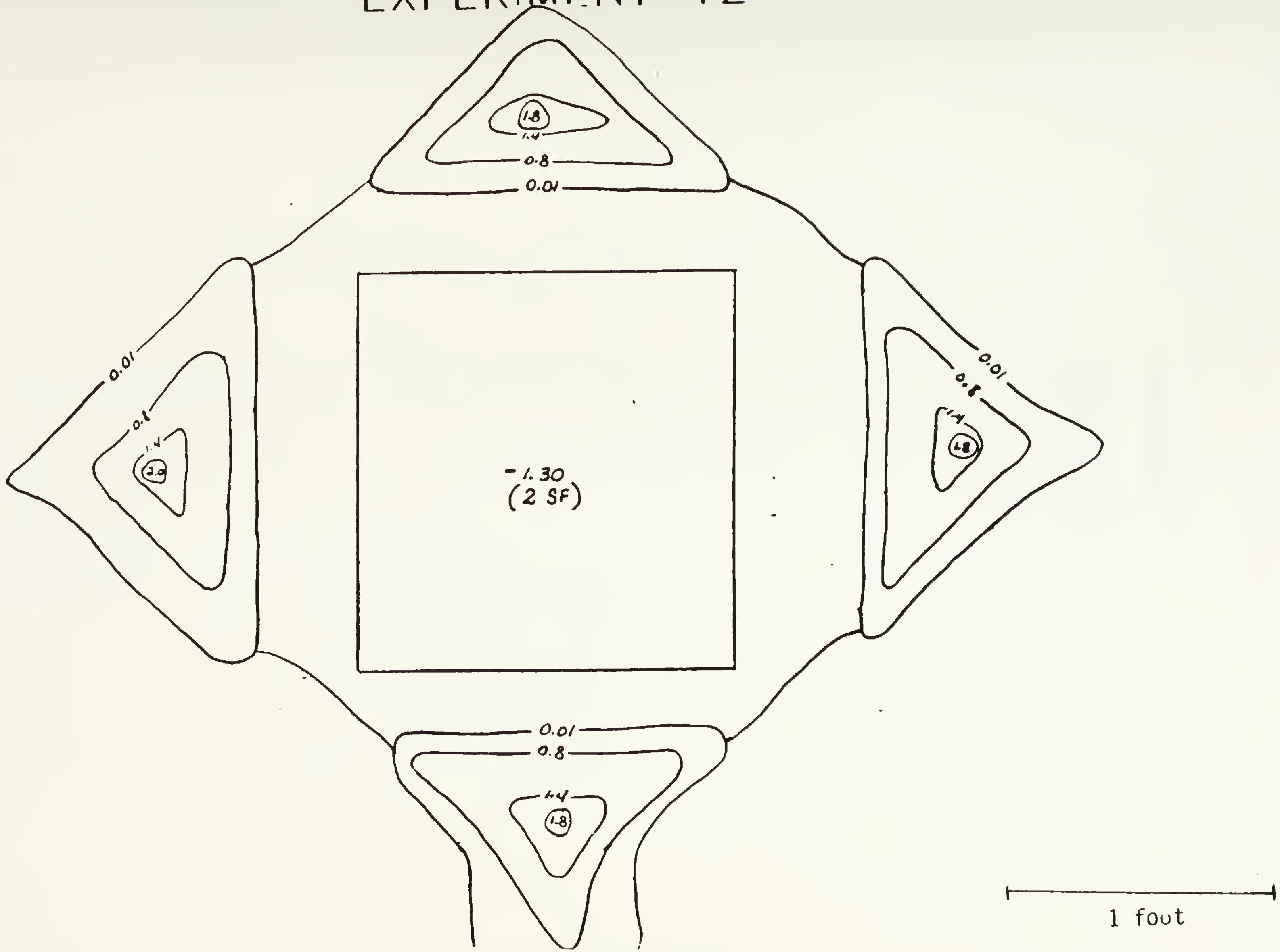


FIGURE C-12

APPENDIX D

SAS OUTPUT

```
NOTE: THE JOB DOIT HAS BEEN RUN UNDER RELEASE 5.16 OF SAS AT TEXAS A&M UNIVERSITY (01452001).

NOTE! CPUID   VERSION = 21  SERIAL = 172328  MODEL = 3090 .
      CPUID   VERSIDN = 21  SERIAL = 272328  MODEL = 3090 .

NDTE: SAS OPTIDNS SPECIFIED ARE:
       SDRT=4

1          DATA DNE; INFILE IN1;
2          INPUT #1 SUBSID #2 T #3 A #4 AP #5 W #6 TH #7 BRHD #8 VISC #9 CYCS
3          #10 PPWS #11 LI #12 PPWP #13 VE $ #14 VPU #15 VPD;


NOTE: INFILE IN1 IS:
      DSNAME=USR.N199.AR.EXP15VAR,
      UNIT=DISK,VOL=SER=USR002,DISP=SHR,
      DCB=(BLKSIZE=6226,LRECL=22,RECFM=FB)

NDTE: 3510 LINES WERE READ FRDM INFILE IN1.
NDTE: DATA SET WORK.DNE HAS 234 DBSERVATIONS AND 15 VARIABLES. 378 DBS/TRK.
NDTE: THE DATA STATEMENT USED 0.12 SECDNDS AND 144K.

4          PRDC SORT;
5           BY SUBSID;

NOTE: 4 CYLINDERS DYNAMICALLY ALLDCATED DN SYSDA FDR EACH DF 3 SDRT WDRK DATA SETS.
NOTE: DATA SET WDRK.DNE HAS 234 DBSERVATIONS AND 15 VARIABLES. 378 OBS/TRK.
NDTE: THE PRDCEDURE SDRT USED 0.16 SECDNDS AND 296K.

6          PRDC PRINT;
NOTE: THE PROCEDURE PRINT USED 0.16 SECDNDS AND 212K AND PRINTED PAGES 1 TD 5.

7          PRDC CORR;
8           VAR SUBSID T A AP W TH BRHD VISC CYCS PPWS LI PPWP VPU VPD;
9          TITLE ' CDRRELATIDN ANALYSIS FDR SUSIDENCE USING: T,A,AP,W,TH BRHD VISC
10         CYCS  PPWS LI PPWP VPU VPD';
NDTE: THE PRDCEDURE CORR USED 0.09 SECDNDS AND 192K AND PRINTED PAGES 6 TO 8.
NOTE: SAS USED 296K MEMDRY.

NOTE: SAS INSTITUTE INC.
      SAS CIRCLE
      PD BDX 8000
      CARY, N.C. 27511-8000
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NOTE: COPYRIGHT (C) 1984,1986 SAS INSTITUTE INC., CARY, N.C.  27511, U.S.A.
NOTE: THE JOB GOTIT HAS BEEN RUN UNDER RELEASE 5.16 OF SAS AT TEXAS A&M UNIVERSITY (01452001).

NOTE: CPUID   VERSION = 21  SERIAL = 172328  MODEL = 3090 .
      CPUID   VERSION = 21  SERIAL = 272328  MODEL = 3090 .

NOTE: SAS OPTIONS SPECIFIED ARE:
       SORT=4

1          DATA ONE; INFILE IN1;
2          INPUT #1 SUBSID #2 T #3 A #4 AP #5 W #6 TH #7 BRHO #8 VISC #9 CYCS
3          #10 PPWS #11 LI #12 PPWP #13 VE $ #14 VPU #15 VPD;


NOTE: INFILE IN1 IS:
      DSNAME=USR.N199.AR.EXP15VAR,
      UNIT=DISK,VOL=SER=USR002,DISP=SHR,
      DCB=(BLKSIZE=6226,LRECL=22,RECFM=FB)

NOTE: 3510 LINES WERE READ FROM INFILE IN1.
NOTE: DATA SET WORK.ONE HAS 234 OBSERVATIONS AND 15 VARIABLES. 378 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.12 SECONDS AND 144K.

4          PROC STEPWISE;
5           MODEL SUBSID=T A AP VISC CYCS PPWS VPU VPD
6                          /FORWARD BACKWARD MAXR;
7          TITLE ' STEPWISE REGRESSION ANALYSIS FOR SUSIDENCE USING: T,A,AP,
8          VISC, CYCS, PPWS, VPU, AND VPD';
NOTE: THE PROCEDURE STEPWISE USED 0.09 SECONDS AND 272K AND PRINTED PAGES 1 TO 9.
NOTE: SAS USED 272K MEMORY.

NOTE: SAS INSTITUTE INC.
      SAS CIRCLE
      PO BOX 8000
      CARY, N.C. 27511-8000
```

FORWARD SELECTION PROCEDURE FOR DEPENDENT VARIABLE SUBSID

STEP 1 VARIABLE CYCS ENTERED R SQUARE = 0.62199808 C(P) = 185.04939267

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	35.74325195	35.74325195	381.75	0.0001
ERROR	232	21.72196044	0.09362914		
TOTAL	233	57.46521239			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.50702011				
CYCS	0.00633395	0.00032418	35.74325195	381.75	0.0001

BOUNDS ON CONDITION NUMBER: 1, 1

STEP 2 VARIABLE VPD ENTERED R SQUARE = 0.76671810 C(P) = 28.14555902

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	44.05961827	22.02980913	379.61	0.0001
ERROR	231	13.40559413	0.05803288		
TOTAL	233	57.46521239			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.02566960				
CYCS	0.00519890	0.00027226	21.16010561	364.62	0.0001
VPD	0.15818428	0.01321398	8.31636632	143.30	0.0001

BOUNDS ON CONDITION NUMBER: 1.13802, 4.552079

STEP 3 VARIABLE VISC ENTERED R SQUARE = 0.77535431 C(P) = 20.66292315

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	3	44.55590002	14.85196667	264.61	0.0001
ERROR	230	12.90931237	0.05612745		
TOTAL	233	57.46521239			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-1.52633020				
VISC	180498.68302602	60701.23389595	0.49628176	8.84	0.0033
CYCS	0.00516436	0.00026801	20.84070122	371.31	0.0001
VPD	0.15639905	0.01300910	8.11239810	144.54	0.0001

BOUNDS ON CONDITION NUMBER: 1.140449, 9.860305

STEP 4 VARIABLE AP ENTERED R SQUARE = 0.78084502 C(P) = 16.63407610

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	44.87142482	11.21785621	203.98	0.0001
ERROR	229	12.59378757	0.05499471		
TOTAL	233	57.46521239			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-2.09545892				
AP	0.08806094	0.03676436	0.31552480	5.74	0.0174
VISC	232913.68266887	63946.28193716	0.72959238	13.27	0.0003
CYCS	0.00547414	0.00029513	18.91961464	344.03	0.0001
VPD	0.14517945	0.01370261	6.17340458	112.25	0.0001

BOUNDS ON CONDITION NUMBER: 1.420018, 21.04838

STEP 5 VARIABLE T ENTERED R SQUARE = 0.78481728 C(P) = 14.27249934

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	5	45.09969163	9.01993833	166.31	0.0001
ERROR	228	12.36552077	0.05423474		
TOTAL	233	57.46521239			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-1.96399756				
†	-0.00495449	0.00241500	0.22826680	4.21	0.0414
AP	0.09574488	0.03670107	0.36910613	6.81	0.0097
VISC	224153.17874265	63646.32176539	0.67269895	12.40	0.0005
CYCS	0.00545322	0.00029327	18.75258798	345.77	0.0001
VPD	0.14401546	0.01361942	6.06426729	111.82	0.0001

BOUNDS ON CONDITION NUMBER: 1.434963, 31.59776

FORWARD SELECTION PROCEDURE FOR DEPENDENT VARIABLE SUBSID

STEP 6 VARIABLE PPWS ENTERED R SQUARE = 0.78953749 C(P) = 11.08966989

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	6	45.37093938	7.56182323	141.93	0.0001
ERROR	227	12.09427301	0.05327874		
TOTAL	233	57.46521239			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-1.72105573				
T	-0.01198702	0.00392985	0.49570742	9.30	0.0026
AP	0.07103360	0.03798907	0.18627917	3.50	0.0628
VISC	216545.59301691	63172.91466856	0.62602371	11.75	0.0007
CYCS	0.00535759	0.00029374	17.72379738	332.66	0.0001
PPWS	1.85197583	0.82078459	0.27124776	5.09	0.0250
VPD	0.16325034	0.01596531	5.57067245	104.56	0.0001

BOUNDS ON CONDITION NUMBER: 3.372361, 72.74012

STEP 7 VARIABLE A ENTERED R SQUARE = 0.79298231 C(P) = 9.30722172

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	7	45.56889700	6.50984243	123.67	0.0001
ERROR	226	11.89631539	0.05263856		
TOTAL	233	57.46521239			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-1.68510212				
T	-0.01178866	0.00390750	0.47910911	9.10	0.0028
A	0.31684658	0.16338603	0.19795762	3.76	0.0537
AP	0.06242312	0.03802030	0.14189394	2.70	0.1020
VISC	182235.98821051	65237.09835771	0.41075518	7.80	0.0057
CYCS	0.00523350	0.00029890	16.13720805	306.57	0.0001
PPWS	1.87373974	0.81591580	0.27760794	5.27	0.0226
VPD	0.16119877	0.01590432	5.40750652	102.73	0.0001

BOUNDS ON CONDITION NUMBER: 3.372999, 94.48934

FORWARD SELECTION PROCEDURE FOR DEPENDENT VARIABLE SUBSID

STEP 8 VARIABLE VPU ENTERED R SQUARE = 0.79508359 C(P) = 9.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	8	45.68964740	5.71120592	109.13	0.0001
ERROR	225	11.77556499	0.05233584		
TOTAL	233	57.46521239			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-1.73874055				
T	-0.01095138	0.00393505	0.40535567	7.75	0.0058
A	0.42042178	0.17661015	0.29657758	5.67	0.0181
AP	0.01313021	0.04990345	0.00362311	0.07	0.7927
VISC	184744.67228012	65070.20511590	0.42187008	8.06	0.0049
CYCS	0.00501678	0.00033043	12.06375136	230.51	0.0001
PPWS	2.51070987	0.91528286	0.39380537	7.52	0.0066
VPU	0.05393236	0.03550625	0.12075040	2.31	0.1302
VPD	0.15774911	0.01602032	5.07447078	96.96	0.0001

BOUNDS ON CONDITION NUMBER: 4.269146, 156.571

NO OTHER VARIABLES MET THE 0.5000 SIGNIFICANCE LEVEL FOR ENTRY INTO THE MODEL.

SUMMARY OF FORWARD SELECTION PROCEDURE FOR DEPENDENT VARIABLE SUBSID

STEP	VARIABLE ENTERED	NUMBER IN	PARTIAL R**2	MODEL R**2	C(P)	F	PROB>F
1	CYCS	1	0.6220	0.6220	185.049	381.7535	0.0001
2	VPD	2	0.1447	0.7667	28.146	143.3044	0.0001
3	VISC	3	0.0086	0.7754	20.663	8.8421	0.0033
4	AP	4	0.0055	0.7808	16.634	5.7374	0.0174
5	T	5	0.0040	0.7848	14.272	4.2089	0.0414
6	PPWS	6	0.0047	0.7895	11.090	5.0911	0.0250
7	A	7	0.0034	0.7930	9.307	3.7607	0.0537
8	VPU	8	0.0021	0.7951	9.000	2.3072	0.1302

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE SUBSID

STEP 0 ALL VARIABLES ENTERED R SQUARE = 0.79508359 C(P) = 9.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	8	45.68964740	5.71120592	109.13	0.0001
ERROR	225	11.77556499	0.05233584		
TOTAL	233	57.46521239			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-1.73874055				
T	-0.01095138	0.00393505	0.40535567	7.75	0.0058
A	0.42042178	0.17661015	0.29657758	5.67	0.0181
AP	0.01313021	0.04990345	0.00362311	0.07	0.7927
VISC	184744.67228012	65070.20511590	0.42187008	8.06	0.0049
CYCS	0.00501678	0.00033043	12.06375136	230.51	0.0001
PPWS	2.51070987	0.91528286	0.39380537	7.52	0.0066
VPU	0.05393236	0.03550625	0.12075040	2.31	0.1302
VPD	0.15774911	0.01602032	5.07447078	96.96	0.0001

BOUNDS ON CONDITION NUMBER: 4.269146, 156.571

STEP 1 VARIABLE AP REMOVED R SQUARE = 0.79502054 C(P) = 7.06922804

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	7	45.68602429	6.52657490	125.22	0.0001
ERROR	226	11.77918810	0.05212030		
TOTAL	233	57.46521239			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-1.69563509				
T	-0.01098545	0.00392481	0.40832403	7.83	0.0056
A	0.43589173	0.16619252	0.35854299	6.88	0.0093
VISC	180469.00022326	62878.50514305	0.42934630	8.24	0.0045
CYCS	0.00496481	0.00026436	18.38321622	352.71	0.0001
PPWS	2.62927738	0.79502023	0.57006367	10.94	0.0011
VPU	0.06000748	0.02691790	0.25902123	4.97	0.0268
VPD	0.15869430	0.01558017	5.40735568	103.75	0.0001

BOUNDS ON CONDITION NUMBER: 3.23429, 93.60242

ALL VARIABLES IN THE MODEL ARE SIGNIFICANT AT THE 0.1000 LEVEL.

SUMMARY OF BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE SUBSID

STEP	VARIABLE REMOVED	NUMBER IN	PARTIAL R**2	MODEL R**2	C(P)	F	PROB>F
1	AP	7	0.0001	0.7950	7.069	0.0692	0.7927

MAXIMUM R-SQUARE IMPROVEMENT FOR OEPENDENT VARIABLE SUBSIO

STEP 1 VARIABLE CYCS ENTEREO R SQUARE = 0.62199808 C(P) = 185.04939267

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	35.74325195	35.74325195	381.75	0.0001
ERROR	232	21.72196044	0.09362914		
TOTAL	233	57.46521239			

	B VALUE	STO ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.50702011				
CYCS	0.00633395	0.00032418	35.74325195	381.75	0.0001

BOUNOS ON CONDITION NUMBER: 1, 1

THE ABOVE MODEL IS THE BEST 1 VARIABLE MOOEL FOUNO.

STEP 2 VARIABLE VPO ENTEREO R SQUARE = 0.76671810 C(P) = 28.14555902

	OF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	44.05961827	22.02980913	379.61	0.0001
ERROR	231	13.40559413	0.05803288		
TOTAL	233	57.46521239			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.02566960				
CYCS	0.00519890	0.00027226	21.16010561	364.62	0.0001
VPO	0.15818428	0.01321398	8.31636632	143.30	0.0001

BOUNOS ON CONOITION NUMBER: 1.13802, 4.552079

THE ABOVE MOOEL IS THE BEST 2 VARIABLE MODEL FOUNO.

STEP 3 VARIABLE VISC ENTEREO R SQUARE = 0.77535431 C(P) = 20.66292315

	OF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	3	44.55590002	14.85196667	264.61	0.0001
ERROR	230	12.90931237	0.05612745		
TOTAL	233	57.46521239			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-1.52633020				
VISC	180498.68302602	60701.23389595	0.49628176	8.84	0.0033
CYCS	0.00516436	0.00026801	20.84070122	371.31	0.0001
VPO	0.15639905	0.01300910	8.11239810	144.54	0.0001

BOUNOS ON CONOITION NUMBER: 1.140449, 9.860305

THE ABOVE MOOEL IS THE BEST 3 VARIABLE MOOEL FOUNO.

STEP 4 VARIABLE AP ENTERED R SQUARE = 0.78084502 C(P) = 16.63407610

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	44.87142482	11.21785621	203.98	0.0001
ERROR	229	12.59378757	0.05499471		
TOTAL	233	57.46521239			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-2.09545892				
AP	0.08806094	0.03676436	0.31552480	5.74	0.0174
VISC	232913.68266887	63946.28193716	0.72959238	13.27	0.0003
CYCS	0.00547414	0.00029513	18.91961464	344.03	0.0001
VPD	0.14517945	0.01370261	6.17340458	112.25	0.0001

BOUNDS ON CONDITION NUMBER: 1.420018, 21.04838

THE ABOVE MODEL IS THE BEST 4 VARIABLE MODEL FOUND.

STEP 5 VARIABLE T ENTERED R SQUARE = 0.78481728 C(P) = 14.27249934

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	5	45.09969163	9.01993833	166.31	0.0001
ERROR	228	12.36552077	0.05423474		
TOTAL	233	57.46521239			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-1.96399756				
T	-0.00495449	0.00241500	0.22826680	4.21	0.0414
AP	0.09574488	0.03670107	0.36910613	6.81	0.0097
VISC	224153.17874265	63646.32176539	0.67269895	12.40	0.0005
CYCS	0.00545322	0.00029327	18.75258798	345.77	0.0001
VPD	0.14401546	0.01361942	6.06426729	111.82	0.0001

BOUNDS ON CONDITION NUMBER: 1.434963, 31.59776

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                MAXIMUM R-SQUARE IMPROVEMENT FOR DEPENDENT VARIABLE SUBSID

STEP 5    AP REPLACED BY PPWS        R SQUARE = 0.78629589     C(P) =    12.64897363

                     DF         SUM OF SQUARES       MEAN SQUARE            F      PROB>F

REGRESSION            5            45.18466022        9.03693204       167.78      0.0001
ERROR               228            12.28055218        0.05386207
TOTAL               233            57.46521239

                B VALUE              STD ERROR      TYPE II SS              F      PROB>F

INTERCEPT   -1.25807609
T           -0.01322978             0.00389438        0.62160086        11.54      0.0008
VISC    177139.01671971         59879.05660026        0.47136964         8.75      0.0034
CYCS         0.00510986             0.00026360       20.23982564       375.77      0.0001
PPWS         2.29442659             0.79022729        0.45407472         8.43      0.0041
VPD          0.17616005             0.01447385        7.97865803       148.13      0.0001

BOUNDS ON CONDITION NUMBER:    3.092079,    47.19345
------------------------------------------------------------------------------------------

THE ABOVE MODEL IS THE BEST  5 VARIABLE MODEL FOUND.

STEP 6    VARIABLE A ENTERED         R SQUARE = 0.79051310     C(P) =    10.01844077

                     DF         SUM OF SQUARES       MEAN SQUARE            F      PROB>F

REGRESSION            6            45.42700306        7.57116718       142.77      0.0001
ERROR               227            12.03820933        0.05303176
TOTAL               233            57.46521239

                B VALUE              STD ERROR      TYPE II SS              F      PROB>F

INTERCEPT   -1.28023747
T           -0.01284627             0.00386841        0.58482461        11.03      0.0010
A            0.34817385             0.16287299        0.24234285         4.57      0.0336
VISC    144686.18493539         61324.52414431        0.29520370         5.57      0.0192
CYCS         0.00500650             0.00026599       18.78728820       354.26      0.0001
PPWS         2.25940702             0.78428387        0.44012741         8.30      0.0043
VPD          0.17218604             0.01448167        7.49712222       141.37      0.0001

BOUNDS ON CONDITION NUMBER:    3.093428,    64.45639
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THE ABOVE MODEL IS THE BEST  6 VARIABLE MODEL FOUND.
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STEP 7 VARIABLE VPU ENTERED R SQUARE = 0.79502054 C(P) = 7.06922804

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	7	45.68602429	6.52657490	125.22	0.0001
ERROR	226	11.77918810	0.05212030		
TOTAL	233	57.46521239			

	B VALUE	STO ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-1.69563509				
T	-0.01098545	0.00392481	0.40832403	7.83	0.0056
A	0.43589173	0.16619252	0.35854299	6.88	0.0093
VISC	180469.00022326	62878.50514305	0.42934630	8.24	0.0045
CYCS	0.00496481	0.00026436	18.38321622	352.71	0.0001
PPWS	2.62927738	0.79502023	0.57006367	10.94	0.0011
VPU	0.06000748	0.02691790	0.25902123	4.97	0.0268
VPO	0.15869430	0.01558017	5.40735568	103.75	0.0001

BOUNOS ON CONOITION NUMBER: 3.23429, 93.60242

THE ABOVE MOOEL IS THE BEST 7 VARIABLE MOOEL FOUNO.

STEP 8 VARIABLE AP ENTEREO R SQUARE = 0.79508359 C(P) = 9.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	8	45.68964740	5.71120592	109.13	0.0001
ERROR	225	11.77556499	0.05233584		
TOTAL	233	57.46521239			

	B VALUE	STO ERROR	TYPE II SS	F	PROB>F
INTERCEPT	-1.73874055				
T	-0.01095138	0.00393505	0.40535567	7.75	0.0058
A	0.42042178	0.17661015	0.29657758	5.67	0.0181
AP	0.01313021	0.04990345	0.00362311	0.07	0.7927
VISC	184744.67228012	65070.20511590	0.42187008	8.06	0.0049
CYCS	0.00501678	0.00033043	12.06375136	230.51	0.0001
PPWS	2.51070987	0.91528286	0.39380537	7.52	0.0066
VPU	0.05393236	0.03550625	0.12075040	2.31	0.1302
VPO	0.15774911	0.01602032	5.07447078	96.96	0.0001

BOUNOS ON CONOITION NUMBER: 4.269146, 156.571

THE ABOVE MOOEL IS THE BEST 8 VARIABLE MOOEL FOUNO.

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NOTE: COPYRIGHT (C) 1984,1986 SAS INSTITUTE INC., CARY, N.C.  27511, U.S.A.
NOTE: THE JOB TRY1 HAS BEEN RUN UNOER RELEASE 5.16 OF SAS AT TEXAS A&M UNIVERSITY (01452001).

NOTE: CPUID   VERSION = 21  SERIAL = 172328  MOOEL = 3090 .
      CPUID   VERSION = 21  SERIAL = 272328  MOOEL = 3090 .

NOTE: SAS OPTIONS SPECIFIEO ARE:
       SORT=4

1          OATA ONE; INFILE IN1;
2          INPUT #1 SUBSIO #2 T #3 A #4 AP #5 W #6 TH #7 BRHO #8 VISC #9 CYCS
3          #10 PPWS #11 LI #12 PPWP #13 VE $ #14 VPU #15 VPD;


NOTE: INFILE IN1 IS:
      OSNAME=USR.N199.AR.EXP15VAR,
      UNIT=OISK,VOL=SER=USROO2,OISP=SHR,
      OCB=(BLKSIZE=6226,LRECL=22,RECFM=FB)

NOTE: 3510 LINES WERE REAO FROM INFILE IN1.
NOTE: OATA SET WORK.ONE HAS 234 OBSERVATIONS ANO 15 VARIABLES. 378 OBS/TRK.
NOTE: THE OATA STATEMENT USEO 0.12 SECONOS ANO 144K.

4          PROC REG;
5          MOOEL SUBSID = T A AP CYCS PPWS VISC VPU VPD / P CLM VIF;
6          TITLE ' REGRESSION ANALYSIS FOR SUSIOENCE USING: T,A,AP,W,TH';
7          ID SUBSID;
8          OUTPUT OUT=REGOUT P=PREO;
NOTE: ACOV ANO SPEC OPTION ONLY VALIO WITH RAWOATA
NOTE: THE OATA SET WORK.REGOUT HAS 234 OBSERVATIONS ANO 16 VARIABLES. 354 OBS/TRK.
NOTE: THE PROCEOURE REG USED 0.17 SECONOS ANO 456K ANO PRINTEO PAGES 1 TO 6.

9          PROC PLOT DATA=REGOUT;
10         PLOT SUBSID*PREO='*';
11         TITLE 'ACTUAL SUBSIDENCE VS PREOICTEO SUBSIOENCE';
NOTE: THE PROCEOURE PLOT USED 0.06 SECONOS ANO 204K ANO PRINTED PAGE 7.
NOTE: SAS USED 456K MEMORY.

NOTE: SAS INSTITUTE INC.
      SAS CIRCLE
      PO BOX 8000
      CARY, N.C. 27511-8000
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OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
18	0	0	0.0594	0.0615	-0.0618	0.1807	-0.0594
19	0.4	0.4000	0.4247	0.0488	0.3285	0.5209	-0.0247
20	0.5	0.5000	0.4389	0.0473	0.3456	0.5321	0.0611
21	0.7	0.7000	0.5458	0.0452	0.4568	0.6347	0.1542
22	0.75	0.7500	0.6342	0.0433	0.5489	0.7195	0.1158
23	0.8	0.8000	0.7202	0.0412	0.6391	0.8013	0.0798
24	0.85	0.8500	0.8074	0.0398	0.7289	0.8858	0.0426
25	0.9	0.9000	0.8424	0.0405	0.7626	0.9221	0.0576
26	1	1.0000	0.9951	0.0387	0.9188	1.0714	.0049005
27	1.1	1.1000	1.0943	0.0387	1.0180	1.1706	0.005694
28	1.25	1.2500	1.2683	0.0397	1.1901	1.3466	-0.0183
29	1.35	1.3500	1.3996	0.0462	1.3085	1.4906	-0.0496
30	1.5	1.5000	1.5843	0.0514	1.4830	1.6856	-0.0843
31	1.6	1.6000	1.7557	0.0583	1.6407	1.8707	-0.1557
32	1.6	1.6000	1.9602	0.0622	1.8376	2.0827	-0.3602
33	1.7	1.7000	2.0941	0.0726	1.9511	2.2370	-0.3941
34	1.7	1.7000	2.2704	0.0793	2.1142	2.4266	-0.5704
35	0	0	0.2237	0.0779	0.0701	0.3772	-0.2237
36	0.2	0.2000	0.5758	0.0462	0.4847	0.6670	-0.3758
37	0.3	0.3000	0.5968	0.0440	0.5101	0.6835	-0.2968
38	0.5	0.5000	0.7165	0.0454	0.6271	0.8060	-0.2165
39	0.6	0.6000	0.7915	0.0461	0.7007	0.8822	-0.1915
40	0.8	0.8000	0.8533	0.0517	0.7515	0.9551	-0.0533
41	0.9	0.9000	0.9204	0.0533	0.8154	1.0253	-0.0204
42	1	1.0000	0.8283	0.0477	0.7344	0.9222	0.1717
43	1.1	1.1000	0.9503	0.0466	0.8584	1.0422	0.1497
44	1.2	1.2000	1.0314	0.0426	0.9475	1.1153	0.1686
45	1.3	1.3000	1.1529	0.0421	1.0699	1.2359	0.1471
46	1.4	1.4000	1.2443	0.0427	1.1601	1.3285	0.1557
47	1.5	1.5000	1.3658	0.0432	1.2806	1.4509	0.1342
48	1.55	1.5500	1.4612	0.0399	1.3826	1.5399	0.0888
49	1.6	1.6000	1.5970	0.0412	1.5159	1.6781	.0029642
50	1.65	1.6500	1.6726	0.0424	1.5890	1.7562	-0.0226
51	1.65	1.6500	1.8300	0.0452	1.7410	1.9190	-0.1800
52	1.7	1.7000	1.9053	0.0471	1.8125	1.9980	-0.2053
53	1.7	1.7000	2.0257	0.0509	1.9254	2.1259	-0.3257
54	1.75	1.7500	2.1009	0.0532	1.9960	2.2059	-0.3509
55	1.75	1.7500	2.1611	0.0556	2.0516	2.2707	-0.4111
56	1.8	1.8000	2.2364	0.0582	2.1218	2.3511	-0.4364
57	1.8	1.8000	2.2966	0.0608	2.1768	2.4164	-0.4966
58	0	0	-0.0247	0.0502	-0.1237	0.0743	0.0247
59	0.05	0.0500	.0044658	0.0494	-0.0929	0.1018	0.0455
60	0.1	0.1000	0.0751	0.0455	-0.0145	0.1646	0.0249
61	0.15	0.1500	0.2057	0.0403	0.1263	0.2851	-0.0557
62	0.2	0.2000	0.2298	0.0397	0.1515	0.3081	-0.0298
63	0.3	0.3000	0.2760	0.0388	0.1996	0.3525	0.0240
64	0.4	0.4000	0.2610	0.0393	0.1837	0.3384	0.1390
65	0.5	0.5000	0.3703	0.0375	0.2964	0.4442	0.1297

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
66	0.6	0.6000	0.5428	0.0389	0.4661	0.6195	0.0572
67	0.7	0.7000	0.6052	0.0398	0.5267	0.6837	0.0948
68	0.8	0.8000	0.6737	0.0411	0.5926	0.7547	0.1263
69	0.9	0.9000	0.7367	0.0426	0.6528	0.8206	0.1633
70	1	1.0000	0.8066	0.0443	0.7194	0.8938	0.1934
71	1.1	1.1000	0.8908	0.0461	0.8000	0.9817	0.2092
72	1.15	1.1500	0.7450	0.0362	0.6736	0.8164	0.4050
73	1.2	1.2000	0.7017	0.0386	0.6257	0.7778	0.4983
74	1.25	1.2500	0.8024	0.0406	0.7224	0.8824	0.4476
75	1.25	1.2500	0.8174	0.0410	0.7365	0.8983	0.4326
76	0	0	0.0848	0.0591	-0.0316	0.2013	-0.0848
77	0.12	0.1200	0.3256	0.0354	0.2558	0.3954	-0.2056
78	0.22	0.2200	0.3828	0.0351	0.3135	0.4520	-0.1628
79	0.4	0.4000	0.4858	0.0360	0.4147	0.5568	-0.0858
80	0.55	0.5500	0.5787	0.0372	0.5054	0.6520	-0.0287
81	0.65	0.6500	0.5967	0.0392	0.5194	0.6740	0.0533
82	0.75	0.7500	0.6687	0.0396	0.5907	0.7467	0.0813
83	0.85	0.8500	0.7373	0.0413	0.6559	0.8187	0.1127
84	1	1.0000	0.8450	0.0430	0.7603	0.9297	0.1550
85	1.1	1.1000	0.8121	0.0371	0.7390	0.8851	0.2879
86	1.15	1.1500	0.9159	0.0391	0.8388	0.9930	0.2341
87	1.2	1.2000	0.8576	0.0378	0.7831	0.9321	0.3424
88	1.3	1.3000	0.9763	0.0394	0.8986	1.0540	0.3237
89	1.3	1.3000	1.0988	0.0396	1.0208	1.1768	0.2012
90	0	0	0.1396	0.0717	-.001601	0.2808	-0.1396
91	0.18	0.1800	0.3204	0.0499	0.2221	0.4187	-0.1404
92	0.3	0.3000	0.3363	0.0420	0.2536	0.4190	-0.0363
93	0.4	0.4000	0.5412	0.0378	0.4667	0.6157	-0.1412
94	0.5	0.5000	0.6107	0.0384	0.5350	0.6864	-0.1107
95	0.6	0.6000	0.6802	0.0394	0.6026	0.7578	-0.0802
96	0.7	0.7000	0.6256	0.0400	0.5469	0.7043	0.0744
97	0.8	0.8000	0.8602	0.0396	0.7822	0.9382	-0.0602
98	0.9	0.9000	0.8183	0.0367	0.7461	0.8906	0.0817
99	1	1.0000	1.0015	0.0448	0.9132	1.0897	-.001453
100	1.02	1.0200	0.7653	0.0365	0.6934	0.8372	0.2547
101	1.02	1.0200	0.8132	0.0410	0.7326	0.8939	0.2068
102	1.02	1.0200	0.8857	0.0397	0.8076	0.9639	0.1343
103	1.1	1.1000	0.9441	0.0403	0.8646	1.0236	0.1559
104	1.1	1.1000	1.4686	0.0470	1.3760	1.5612	-0.3686
105	0	0	0.0725	0.0566	-0.0389	0.1840	-0.0725
106	0.12	0.1200	0.4660	0.0364	0.3943	0.5376	-0.3460
107	0.2	0.2000	0.5048	0.0357	0.4344	0.5752	-0.3048
108	0.22	0.2200	0.5188	0.0359	0.4481	0.5894	-0.2988
109	0.3	0.3000	0.5324	0.0389	0.4557	0.6091	-0.2324
110	0.38	0.3800	0.5772	0.0391	0.5003	0.6542	-0.1972
111	0.45	0.4500	0.6211	0.0385	0.5451	0.6970	-0.1711
112	0.5	0.5000	0.6567	0.0383	0.5813	0.7321	-0.1567
113	0.6	0.6000	0.5867	0.0386	0.5105	0.6628	0.0133

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
114	0.7	0.7000	0.8004	0.0367	0.7280	0.8727	-0.1004
115	0.72	0.7200	0.8176	0.0364	0.7458	0.8893	-0.0976
116	0.77	0.7700	0.8531	0.0368	0.7806	0.9257	-0.0831
117	0.85	0.8500	0.8994	0.0382	0.8242	0.9746	-0.0494
118	0.95	0.9500	0.9824	0.0407	0.9021	1.0626	-0.0324
119	1	1.0000	1.0104	0.0417	0.9281	1.0926	-0.0104
120	1.02	1.0200	1.0261	0.0421	0.9431	1.1090	-.006064
121	1.05	1.0500	1.0459	0.0427	0.9617	1.1300	.0041301
122	1.08	1.0800	1.0657	0.0433	0.9803	1.1510	0.0143
123	1.1	1.1000	1.0814	0.0437	0.9952	1.1675	0.0186
124	1.15	1.1500	1.1169	0.0448	1.0286	1.2052	0.0331
125	1.2	1.2000	1.1449	0.0460	1.0543	1.2355	0.0551
126	1.25	1.2500	1.1804	0.0472	1.0875	1.2733	0.0696
127	1.3	1.3000	1.2159	0.0484	1.1207	1.3112	0.0841
128	1.35	1.3500	1.2515	0.0496	1.1537	1.3492	0.0985
129	1.4	1.4000	1.2870	0.0509	1.1867	1.3872	0.1130
130	1.45	1.4500	1.3206	0.0525	1.2170	1.4241	0.1294
131	1.6	1.6000	0.8250	0.0371	0.7518	0.8982	0.7750
132	1.6	1.6000	1.2076	0.0336	1.1414	1.2737	0.3924
133	0	0	0.1821	0.0618	0.0603	0.3038	-0.1821
134	0.15	0.1500	0.6302	0.0431	0.5452	0.7152	-0.4802
135	0.22	0.2200	0.4360	0.0444	0.3485	0.5234	-0.2160
136	0.32	0.3200	0.5167	0.0384	0.4410	0.5924	-0 1967
137	0.45	0.4500	0.6086	0.0342	0.5412	0.6759	-0.1586
138	0.55	0.5500	0.9087	0.0454	0.8193	0.9980	-0.3587
139	0.6	0.6000	0.7894	0.0352	0.7200	0.8587	-0.1894
140	0.7	0.7000	0.4700	0.0401	0.3910	0.5491	0.2300
141	0.75	0.7500	0.5110	0.0423	0.4276	0.5943	0.2390
142	0.85	0.8500	0.9406	0.0365	0.8686	1.0126	-0.0906
143	0.9	0.9000	0.6185	0.0331	0.5532	0.6838	0.2815
144	1	1.0000	0.6571	0.0321	0.5939	0.7203	0.3429
145	1.08	1.0800	0.9193	0.0309	0.8583	0.9802	0.1607
146	1.2	1.2000	0.7845	0.0322	0.7211	0.8480	0.4155
147	1.3	1.3000	0.8305	0.0321	0.7672	0.8937	0.4695
148	1.4	1.4000	0.7775	0.0333	0.7119	0.8431	0.6225
149	1.5	1.5000	0.8308	0.0341	0.7636	0.8980	0.6692
150	1.55	1.5500	0.9609	0.0343	0.8934	1.0285	0.5891
151	1.62	1.6200	1.0764	0.0340	1.0094	1.1433	0.5436
152	1.65	1.6500	1.1256	0.0337	1.0592	1.1920	0.5244
153	1.7	1.7000	1.3216	0.0414	1.2400	1.4032	0.3784
154	1.72	1.7200	1.2306	0.0398	1.1522	1.3091	0.4894
155	0	0	0.2368	0.0727	0.0935	0.3801	-0.2368
156	0.2	0.2000	0.4917	0.0662	0.3613	0.6222	-0.2917
157	0.35	0.3500	0.5965	0.0527	0.4928	0.7003	-0.2465
158	0.5	0.5000	0.6959	0.0487	0.5999	0.7920	-0.1959
159	0.7	0.7000	0.8184	0.0449	0.7299	0.9069	-0.1184
160	0.8	0.8000	0.8947	0.0436	0.8087	0.9806	-0.0947
161	0.9	0.9000	0.9709	0.0428	0.8865	1.0553	-0.0709

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
162	1	1.0000	1.0472	0.0425	0.9634	1.1310	-0.0472
163	1.1	1.1000	1.1775	0.0394	1.0997	1.2552	-0.0775
164	1.2	1.2000	1.2538	0.0417	1.1716	1.3359	-0.0538
165	1.25	1.2500	1.3069	0.0426	1.2230	1.3909	-0.0569
166	1.35	1.3500	1.0203	0.0490	0.9238	1.1169	0.3297
167	1.4	1.4000	1.0616	0.0400	0.9828	1.1403	0.3384
168	1.5	1.5000	1.1234	0.0396	1.0453	1.2014	0.3766
169	1.55	1.5500	1.2307	0.0471	1.1379	1.3234	0.3193
170	1.6	1.6000	1.2422	0.0366	1.1702	1.3143	0.3578
171	1.65	1.6500	1.6245	0.0551	1.5160	1.7330	0.0255
172	0	0	-0.0115	0.0558	-0.1214	0.0984	0.0115
173	0.1	0.1000	0.3940	0.0435	0.3083	0.4798	-0.2940
174	0.12	0.1200	0.3636	0.0329	0.2987	0.4285	-0.2436
175	0.2	0.2000	0.3919	0.0331	0.3266	0.4571	-0.1919
176	0.21	0.2100	0.4040	0.0330	0.3390	0.4690	-0.1940
177	0.22	0.2200	0.4161	0.0329	0.3513	0.4809	-0.1961
178	0.25	0.2500	0.4564	0.0320	0.3934	0.5194	-0.2064
179	0.3	0.3000	0.4757	0.0323	0.4121	0.5392	-0.1757
180	0.35	0.3500	0.5138	0.0321	0.4506	0.5770	-0.1638
181	0.4	0.4000	0.5249	0.0341	0.4577	0.5922	-0.1249
182	0.45	0.4500	0.6171	0.0336	0.5509	0.6833	-0.1671
183	0.5	0.5000	0.4735	0.0391	0.3965	0.5506	0.0265
184	0.52	0.5200	0.4774	0.0353	0.4078	0.5469	0.0426
185	0.6	0.6000	0.5178	0.0349	0.4489	0.5866	0.0822
186	0.65	0.6500	0.5520	0.0404	0.4724	0.6316	0.0980
187	0.67	0.6700	0.5377	0.0375	0.4637	0.6116	0.1323
188	0.7	0.7000	0.7688	0.0348	0.7003	0.8374	-0.0688
189	0.75	0.7500	0.8340	0.0364	0.7623	0.9057	-0.0840
190	0.8	0.8000	0.8721	0.0376	0.7981	0.9461	-0.0721
191	0.82	0.8200	0.8964	0.0380	0.8216	0.9712	-0.0764
192	0.88	0.8800	0.9392	0.0396	0.8611	1.0172	-0.0592
193	0.9	0.9000	0.9634	0.0401	0.8845	1.0424	-0.0634
194	0.95	0.9500	0.9896	0.0392	0.9124	1.0669	-0.0396
195	1.01	1.0100	1.0474	0.0406	0.9674	1.1275	-0.0374
196	1.03	1.0300	1.1138	0.0435	1.0280	1.1996	-0.0838
197	1.08	1.0800	1.1400	0.0424	1.0564	1.2236	-0.0600
198	1.1	1.1000	1.1643	0.0430	1.0796	1.2489	-0.0643
199	1.15	1.1500	1.2024	0.0444	1.1148	1.2899	-0.0524
200	1.12	1.1200	1.2186	0.0436	1.1328	1.3045	-0.0986
201	1.15	1.1500	1.2475	0.0445	1.1599	1.3351	-0.0975
202	1.18	1.1800	1.2765	0.0454	1.1871	1.3658	-0.0965
203	1.18	1.1800	1.2915	0.0454	1.2020	1.3810	-0.1115
204	0	0	0.0980	0.0628	-0.0258	0.2218	-0.0980
205	0.1	0.1000	0.4031	0.0323	0.3394	0.4668	-0.3031
206	0.15	0.1500	0.4048	0.0354	0.3350	0.4747	-0.2548
207	0.25	0.2500	0.4931	0.0306	0.4328	0.5533	-0.2431
208	0.3	0.3000	0.5420	0.0301	0.4826	0.6014	-0.2420
209	0.38	0.3800	0.5994	0.0301	0.5400	0.6588	-0.2194

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
210	0.48	0.4800	0.6606	0.0305	0.6006	0.7206	-0.1806
211	0.52	0.5200	0.6941	0.0308	0.6335	0.7547	-0.1741
212	0.6	0.6000	0.7461	0.0318	0.6835	0.8088	-0.1461
213	0.7	0.7000	0.8062	0.0306	0.7459	0.8665	-0.1062
214	0.8	0.8000	0.8663	0.0301	0.8069	0.9256	-0.0663
215	0.9	0.9000	0.7353	0.0331	0.6700	0.8006	0.1647
216	1	1.0000	0.8011	0.0330	0.7361	0.8662	0.1989
217	1.05	1.0500	0.8471	0.0336	0.7809	0.9133	0.2029
218	1.1	1.1000	0.9186	0.0415	0.8369	1.0004	0.1814
219	1.15	1.1500	0.9390	0.0351	0.8699	1.0081	0.2110
220	1.2	1.2000	1.2748	0.0506	1.1750	1.3746	-0.0748
221	1.21	1.2100	1.3095	0.0507	1.2095	1.4095	-0.0995
222	0	0	0.1527	0.0743	.0062281	0.2992	-0.1527
223	0.2	0.2000	0.4152	0.0448	0.3269	0.5035	-0.2152
224	0.4	0.4000	0.5242	0.0439	0.4377	0.6106	-0.1242
225	0.52	0.5200	0.5935	0.0440	0.5069	0.6801	-0.0735
226	0.7	0.7000	0.6959	0.0419	0.6133	0.7786	.0040846
227	0.8	0.8000	0.8262	0.0350	0.7572	0.8951	-0.0262
228	0.9	0.9000	0.9025	0.0354	0.8326	0.9723	-.002455
229	1	1.0000	0.9787	0.0365	0.9069	1.0506	0.0213
230	1.1	1.1000	1.0550	0.0381	0.9800	1.1300	0.0450
231	1.12	1.1200	1.0943	0.0384	1.0187	1.1700	0.0257
232	1.15	1.1500	1.1653	0.0424	1.0817	1.2488	-0.0153
233	1.2	1.2000	0.9396	0.0380	0.8647	1.0145	0.2604
234	1.3	1.3000	1.0506	0.0384	0.9749	1.1263	0.2494

SUM OF RESIDUALS	-7.87162E-13
SUM OF SQUARED RESIDUALS	11.77556
PREDICTED RESID SS (PRESS)	12.78771

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NOTE: COPYRIGHT (C) 1984,1986 SAS INSTITUTE INC., CARY, N.C.  27511, U.S.A.
NDTE: THE JDB TRY1 HAS BEEN RUN UNDER RELEASE 5.16 DF SAS AT TEXAS A&M UNIVERSITY (01452001).

NOTE: CPUID   VERSIDN = 21  SERIAL = 172328  MDDEL = 3090 .
      CPUID   VERSION = 21  SERIAL = 272328  MDDEL = 3090 .

NOTE: SAS OPTIONS SPECIFIED ARE:
       SDRT=4

1           DATA ONE; INFILE IN1;
2           INPUT #1 SUBSID #2 T #3 A #4 AP #5 W #6 TH #7 BRHD #8 VISC #9 CYCS
3           #10 PPWS #11 LI #12 PPWP #13 VE $ #14 VPU #15 VPD;


NDTE: INFILE IN1 IS:
      DSNAME=USR.N199.AR.EXP15VAR,
      UNIT=DISK,VDL=SER=USR002,DISP=SHR,
      DCB=(BLKSIZE=6226,LRECL=22,RECFM=FB)

NOTE: 3510 LINES WERE READ FROM INFILE IN1
NDTE: DATA SET WDRK.DNE HAS 234 DBSERVATIDNS AND 15 VARIABLES. 378 DBS/TRK.
NDTE: THE DATA STATEMENT USED 0.12 SECONDS AND 144K.

4           PROC REG;
5           MODEL SUBSID = T AP CYCS PPWS VISC VPD / P CLM VIF;
6           TITLE ' REGRESSIDN ANALYSIS FDR SUSIDENCE USING:T,AP,CYCS,PPWS,VISC,VPD';
7           ID SUBSID;
8           OUTPUT DUT=REGDUT P=PRED;
NDTE: ACDV AND SPEC DPTIDN DNLY VALID WITH RAWDATA
NDTE: THE DATA SET WORK.REGDUT HAS 234 DBSERVATIDNS AND 16 VARIABLES. 354 DBS/TRK.
NDTE: THE PRDCEDURE REG USED 0.16 SECDNDS AND 456K AND PRINTED PAGES 1 TD 6.
 .
9           PRDC PLDT DATA=REGOUT;
10          PLDT SUBSID*PRED='*';
11          TITLE 'ACTUAL SUBSIDENCE VS PREDICTED SUBSIDENCE';
NDTE: THE PRDCEDURE PLOT USED 0.06 SECDNDS AND 204K AND PRINTED PAGE 7.
NDTE: SAS USED 456K MEMORY.

NDTE: SAS INSTITUTE INC.
      SAS CIRCLE
      PO BDX 8000
      CARY, N.C. 27511-8000
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OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
20	0.5	0.5000	0.3610	0.0355	0.2909	0.4310	0.1390
21	0.7	0.7000	0.4719	0.0341	0.4047	0.5391	0.2281
22	0.75	0.7500	0.5639	0.0329	0.4991	0.6287	0.1861
23	0.8	0.8000	0.6559	0.0322	0.5926	0.7193	0.1441
24	0.85	0.8500	0.7480	0.0319	0.6850	0.8109	0.1020
25	0.9	0.9000	0.7846	0.0333	0.7190	0.8502	0.1154
26	1	1.0000	0.9437	0.0328	0.8790	1.0084	0.0563
27	1.1	1.1000	1.0474	0.0339	0.9806	1.1142	0.0526
28	1.25	1.2500	1.2351	0.0372	1.1619	1.3084	0.0149
29	1.35	1.3500	1.3873	0.0443	1.3000	1.4746	-0.0373
30	1.5	1.5000	1.5830	0.0494	1.4857	1.6803	-0.0830
31	1.6	1.6000	1.7671	0.0555	1.6577	1.8764	-0.1671
32	1.6	1.6000	1.9676	0.0610	1.8474	2.0879	-0.3676
33	1.7	1.7000	2.1238	0.0687	1.9885	2.2591	-0.4238
34	1.7	1.7000	2.3044	0.0757	2.1552	2.4537	-0.6044
35	0	0	0.1463	0.0719	0.004555	0.2880	-0.1463
36	0.2	0.2000	0.5089	0.0378	0.4344	0.5834	-0.3089
37	0.3	0.3000	0.5420	0.0379	0.4673	0.6168	-0.2420
38	0.5	0.5000	0.6558	0.0385	0.5800	0.7316	-0.1558
39	0.6	0.6000	0.7288	0.0387	0.6524	0.8051	-0.1288
40	0.8	0.8000	0.7676	0.0362	0.6963	0.8388	0.0324
41	0.9	0.9000	0.8324	0.0367	0.7600	0.9048	0.0676
42	1	1.0000	0.7485	0.0334	0.6827	0.8144	0.2515
43	1.1	1.1000	0.8722	0.0321	0.8089	0.9354	0.2278
44	1.2	1.2000	0.9637	0.0316	0.9013	1.0260	0.2363
45	1.3	1.3000	1.0873	0.0315	1.0253	1.1493	0.2127
46	1.4	1.4000	1.1788	0.0318	1.1161	1.2415	0.2212
47	1.5	1.5000	1.3024	0.0328	1.2378	1.3671	0.1976
48	1.55	1.5500	1.4125	0.0343	1.3448	1.4801	0.1375
49	1.6	1.6000	1.5547	0.0372	1.4813	1.6280	0.0453
50	1.65	1.6500	1.6326	0.0390	1.5557	1.7095	0.0174
51	1.65	1.6500	1.8010	0.0439	1.7145	1.8875	-0.1510
52	1.7	1.7000	1.8789	0.0462	1.7879	1.9699	-0.1789
53	1.7	1.7000	2.0074	0.0508	1.9074	2.1075	-0.3074
54	1.75	1.7500	2.0853	0.0533	1.9803	2.1904	-0.3353
55	1.75	1.7500	2.1496	0.0559	2.0395	2.2598	-0.3996
56	1.8	1.8000	2.2275	0.0586	2.1121	2.3430	-0.4275
57	1.8	1.8000	2.2918	0.0613	2.1710	2.4126	-0.4918
58	0	0	-0.0335	0.0490	-0.1301	0.0630	0.0335
59	0.05	0.0500	0.0105	0.0493	-0.0867	0.1077	0.0395
60	0.1	0.1000	0.0866	0.0454	-.002814	0.1759	0.0134
61	0.15	0.1500	0.2211	0.0399	0.1425	0.2998	-0.0711
62	0.2	0.2000	0.2455	0.0393	0.1680	0.3229	-0.0455
63	0.3	0.3000	0.2942	0.0382	0.2189	0.3695	.0057996
64	0.4	0.4000	0.2776	0.0388	0.2013	0.3540	0.1224
65	0.5	0.5000	0.3916	0.0367	0.3194	0.4639	0.1084
66	0.6	0.6000	0.5707	0.0375	0.4968	0.6446	0.0293
67	0.7	0.7000	0.6356	0.0382	0.5604	0.7109	0.0644

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
68	0.8	0.8000	0.7086	0.0389	0.6319	0.7853	0.0914
69	0.9	0.9000	0.7735	0.0402	0.6942	0.8528	0.1265
70	1	1.0000	0.8465	0.0416	0.7645	0.9284	0.1535
71	1.1	1.1000	0.9355	0.0428	0.8512	1.0198	0.1645
72	1.15	1.1500	0.7871	0.0323	0.7235	0.8506	0.3629
73	1.2	1.2000	0.7450	0.0347	0.6767	0.8133	0.4550
74	1.25	1.2500	0.8516	0.0356	0.7815	0.9218	0.3984
75	1.25	1.2500	0.8677	0.0359	0.7970	0.9384	0.3823
76	0	0	0.0863	0.0590	-0.0298	0.2025	-0.0863
77	0.12	0.1200	0.3584	0.0331	0.2933	0.4236	-0.2384
78	0.22	0.2200	0.4153	0.0328	0.3506	0.4800	-0.1953
79	0.4	0.4000	0.5209	0.0334	0.4552	0.5867	-0.1209
80	0.55	0.5500	0.6143	0.0346	0.5461	0.6825	-0.0643
81	0.65	0.6500	0.6474	0.0330	0.5824	0.7125	.0025689
82	0.75	0.7500	0.7204	0.0333	0.6547	0.7861	0.0296
83	0.85	0.8500	0.7933	0.0340	0.7263	0.8604	0.0567
84	1	1.0000	0.9028	0.0357	0.8324	0.9732	0.0972
85	1.1	1.1000	0.8689	0.0287	0.8122	0.9255	0.2311
86	1.15	1.1500	0.9816	0.0277	0.9271	1.0362	0.1684
87	1.2	1.2000	0.9213	0.0268	0.8684	0.9741	0.2787
88	1.3	1.3000	1.0449	0.0270	0.9917	1.0981	0.2551
89	1.3	1.3000	1.1638	0.0295	1.1057	1.2219	0.1362
90	0	0	0.1463	0.0719	0.004555	0.2880	-0.1463
91	0.18	0.1800	0.3395	0.0492	0.2426	0.4363	-0.1595
92	0.3	0.3000	0.3706	0.0399	0.2919	0.4493	-0.0706
93	0.4	0.4000	0.5732	0.0358	0.5027	0.6436	-0.1732
94	0.5	0.5000	0.6461	0.0359	0.5754	0.7169	-0.1461
95	0.6	0.6000	0.7191	0.0364	0.6474	0.7908	-0.1191
96	0.7	0.7000	0.6819	0.0322	0.6185	0.7453	0.0181
97	0.8	0.8000	0.9094	0.0345	0.8414	0.9774	-0.1094
98	0.9	0.9000	0.8635	0.0321	0.8003	0.9267	0.0365
99	1	1.0000	1.0676	0.0355	0.9976	1.1375	-0.0676
100	1.02	1.0200	0.8084	0.0323	0.7449	0.8720	0.2116
101	1.02	1.0200	0.8727	0.0330	0.8077	0.9377	0.1473
102	1.02	1.0200	0.9370	0.0341	0.8699	1.0042	0.0830
103	1.1	1.1000	0.9746	0.0368	0.9021	1.0470	0.1254
104	1.1	1.1000	1.5339	0.0392	1.4567	1.6111	-0.4339
105	0	0	0.0375	0.0515	-0.0640	0.1390	-0.0375
106	0.12	0.1200	0.4429	0.0288	0.3861	0.4997	-0.3229
107	0.2	0.2000	0.4836	0.0279	0.4287	0.5385	-0.2836
108	0.22	0.2200	0.4998	0.0276	0.4453	0.5542	-0.2798
109	0.3	0.3000	0.5206	0.0298	0.4618	0.5793	-0.2206
110	0.38	0.3800	0.5693	0.0290	0.5121	0.6265	-0.1893
111	0.45	0.4500	0.6139	0.0285	0.5577	0.6701	-0.1639
112	0.5	0.5000	0.6504	0.0283	0.5947	0.7061	-0.1504
113	0.6	0.6000	0.5767	0.0297	0.5181	0.6353	0.0233
114	0.7	0.7000	0.7921	0.0283	0.7365	0.8478	-0.0921
115	0.72	0.7200	0.8083	0.0285	0.7523	0.8644	-0.0883

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
116	0.77	0.7700	0.8448	0.0291	0.7875	0.9021	-0.0748
117	0.85	0.8500	0.8935	0.0304	0.8336	0.9534	-0.0435
118	0.95	0.9500	0.9703	0.0357	0.9000	1.0407	-0.0203
119	1	1.0000	0.9988	0.0370	0.9259	1.0716	.0012292
120	1.02	1.0200	1.0150	0.0374	0.9413	1.0887	.0050303
121	1.05	1.0500	1.0352	0.0381	0.9601	1.1104	0.0148
122	1.08	1.0800	1.0555	0.0389	0.9789	1.1321	0.0245
123	1.1	1.1000	1.0717	0.0393	0.9942	1.1493	0.0283
124	1.15	1.1500	1.1082	0.0406	1.0282	1.1882	0.0418
125	1.2	1.2000	1.1367	0.0420	1.0538	1.2195	0.0633
126	1.25	1.2500	1.1731	0.0434	1.0877	1.2586	0.0769
127	1.3	1.3000	1.2096	0.0447	1.1215	1.2977	0.0904
128	1.35	1.3500	1.2461	0.0461	1.1552	1.3370	0.1039
129	1.4	1.4000	1.2826	0.0475	1.1889	1.3762	0.1174
130	1.45	1.4500	1.3190	0.0490	1.2225	1.4156	0.1310
131	1.6	1.6000	0.8079	0.0327	0.7435	0.8723	0.7921
132	1.6	1.6000	1.1873	0.0312	1.1259	1.2487	0.4127
133	0	0	0.1574	0.0568	0.0455	0.2693	-0.1574
134	0.15	0.1500	0.6400	0.0278	0.5851	0.6948	-0.4900
135	0.22	0.2200	0.4286	0.0361	0.3575	0.4997	-0.2086
136	0.32	0.3200	0.4773	0.0341	0.4101	0.5445	-0.1573
137	0.45	0.4500	0.5557	0.0269	0.5028	0.6086	-0.1057
138	0.55	0.5500	0.9219	0.0328	0.8574	0.9865	-0.3719
139	0.6	0.6000	0.7874	0.0246	0.7390	0.8358	-0.1874
140	0.7	0.7000	0.4280	0.0357	0.3576	0.4983	0.2720
141	0.75	0.7500	0.4522	0.0353	0.3827	0.5217	0.2978
142	0.85	0.8500	0.9376	0.0287	0.8810	0.9942	-0.0876
143	0.9	0.9000	0.5864	0.0286	0.5301	0.6427	0.3136
144	1	1.0000	0.6228	0.0275	0.5686	0.6771	0.3772
145	1.08	1.0800	0.9099	0.0240	0.8626	0.9572	0.1701
146	1.2	1.2000	0.7517	0.0280	0.6965	0.8069	0.4483
147	1.3	1.3000	0.8042	0.0280	0.7490	0.8595	0.4958
148	1.4	1.4000	0.7389	0.0291	0.6815	0.7963	0.6611
149	1.5	1.5000	0.8073	0.0304	0.7474	0.8672	0.6927
150	1.55	1.5500	0.9517	0.0289	0.8947	1.0087	0.5983
151	1.62	1.6200	1.0624	0.0307	1.0019	1.1230	0.5576
152	1.65	1.6500	1.0986	0.0315	1.0366	1.1606	0.5514
153	1.7	1.7000	1.3267	0.0362	1.2553	1.3981	0.3733
154	1.72	1.7200	1.1992	0.0379	1.1244	1.2739	0.5208
155	0	0	0.2173	0.0683	0.0827	0.3519	-0.2173
156	0.2	0.2000	0.4605	0.0647	0.3331	0.5879	-0.2605
157	0.35	0.3500	0.5937	0.0470	0.5011	0.6862	-0.2437
158	0.5	0.5000	0.6870	0.0446	0.5992	0.7749	-0.1870
159	0.7	0.7000	0.8008	0.0424	0.7173	0.8843	-0.1008
160	0.8	0.8000	0.8738	0.0416	0.7918	0.9557	-0.0738
161	0.9	0.9000	0.9467	0.0411	0.8657	1.0278	-0.0467
162	1	1.0000	1.0197	0.0410	0.9389	1.1004	-0.0197
163	1.1	1.1000	1.1324	0.0351	1.0633	1.2016	-0.0324

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
164	1.2	1.2000	1.2054	0.0365	1.1334	1.2774	-.005404
165	1.25	1.2500	1.2580	0.0372	1.1846	1.3313	-.007956
166	1.35	1.3500	0.9714	0.0448	0.8831	1.0597	0.3786
167	1.4	1.4000	1.0371	0.0385	0.9611	1.1130	0.3629
168	1.5	1.5000	1.0964	0.0382	1.0212	1.1716	0.4036
169	1.55	1.5500	1.1621	0.0337	1.0956	1.2285	0.3879
170	1.6	1.6000	1.2078	0.0341	1.1407	1.2750	0.3922
171	1.65	1.6500	1.5987	0.0545	1.4914	1.7061	0.0513
172	0	0	0.0375	0.0515	-0.0640	0.1390	-0.0375
173	0.1	0.1000	0.3730	0.0304	0.3132	0.4329	-0.2730
174	0.12	0.1200	0.3813	0.0306	0.3209	0.4416	-0.2613
175	0.2	0.2000	0.4100	0.0307	0.3496	0.4704	-0.2100
176	0.21	0.2100	0.4221	0.0305	0.3621	0.4821	-0.2121
177	0.22	0.2200	0.4342	0.0303	0.3746	0.4939	-0.2142
178	0.25	0.2500	0.4685	0.0283	0.4128	0.5241	-0.2185
179	0.3	0.3000	0.4910	0.0289	0.4341	0.5479	-0.1910
180	0.35	0.3500	0.5275	0.0281	0.4721	0.5828	-0.1775
181	0.4	0.4000	0.5441	0.0309	0.4831	0.6050	-0.1441
182	0.45	0.4500	0.6203	0.0263	0.5686	0.6721	-0.1703
183	0.5	0.5000	0.4720	0.0323	0.4083	0.5357	0.0280
184	0.52	0.5200	0.4935	0.0322	0.4301	0.5569	0.0265
185	0.6	0.6000	0.5314	0.0311	0.4701	0.5927	0 0686
186	0.65	0.6500	0.5491	0.0323	0.4855	0.6127	C.1009
187	0.67	0.6700	0.5587	0.0346	0.4905	0.6268	0.1113
188	0.7	0.7000	0.7790	0.0277	0.7244	0.8336	-0.0790
189	0.75	0.7500	0.8354	0.0259	0.7844	0.8864	-0.0854
190	0.8	0.8000	0.8719	0.0261	0.8204	0.9234	-0.0719
191	0.82	0.8200	0.8961	0.0263	0.8443	0.9479	-0.0761
192	0.88	0.8800	0.9367	0.0268	0.8838	0.9895	-0.0567
193	0.9	0.9000	0.9609	0.0270	0.9076	1.0142	-0.0609
194	0.95	0.9500	0.9935	0.0282	0.9380	1.0491	-0.0435
195	1.01	1.0100	1.0502	0.0288	0.9935	1.1069	-0.0402
196	1.03	1.0300	1.1104	0.0291	1.0531	1.1677	-0.0804
197	1.08	1.0800	1.1430	0.0299	1.0841	1.2020	-0.0630
198	1.1	1.1000	1.1673	0.0303	1.1076	1.2269	-0.0673
199	1.15	1.1500	1.2037	0.0310	1.1427	1.2648	-0.0537
200	1.12	1.1200	1.2236	0.0311	1.1623	1.2850	-0.1036
201	1.15	1.1500	1.2520	0.0316	1.1896	1.3143	-0.1020
202	1.18	1.1800	1.2803	0.0322	1.2169	1.3437	-0.1003
203	1.18	1.1800	1.2964	0.0325	1.2324	1.3603	-0.1164
204	0	0	0.1574	0.0568	0.0455	0.2693	-0.1574
205	0.1	0.1000	0.4213	0.0292	0.3639	0.4788	-0.3213
206	0.15	0.1500	0.4578	0.0280	0.4026	0.5130	-0.3078
207	0.25	0.2500	0.5346	0.0257	0.4839	0.5853	-0.2846
208	0.3	0.3000	0.5790	0.0260	0.5278	0.6303	-0.2790
209	0.38	0.3800	0.6317	0.0264	0.5798	0.6837	-0.2517
210	0.48	0.4800	0.6886	0.0265	0.6363	0.7409	-0.2086
211	0.52	0.5200	0.7210	0.0267	0.6685	0.7735	-0.2010

PREDICT STD ERR LOWER95% UPPER95%

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
212	0.6	0.6000	0.7697	0.0273	0.7160	0.8235	-0.1697
213	0.7	0.7000	0.8307	0.0253	0.7808	0.8807	-0.1307
214	0.8	0.8000	0.8918	0.0241	0.8442	0.9393	-0.0918
215	0.9	0.9000	0.7454	0.0250	0.6960	0.7947	0.1546
216	1	1.0000	0.8247	0.0279	0.7697	0.8796	0.1753
217	1.05	1.0500	0.8704	0.0281	0.8150	0.9258	0.1796
218	1.1	1.1000	0.9161	0.0285	0.8600	0.9723	0.1839
219	1.15	1.1500	0.9619	0.0289	0.9049	1.0189	0.1881
220	1.2	1.2000	1.2797	0.0404	1.2000	1.3594	-0.0797
221	1.21	1.2100	1.3160	0.0406	1.2359	1.3960	-0.1060
222	0	0	0.2173	0.0683	0.0827	0.3519	-0.2173
223	0.2	0.2000	0.4585	0.0415	0.3766	0.5404	-0.2585
224	0.4	0.4000	0.5922	0.0330	0.5271	0.6573	-0.1922
225	0.52	0.5200	0.6613	0.0336	0.5952	0.7275	-0.1413
226	0.7	0.7000	0.7590	0.0333	0.6934	0.8245	-0.0590
227	0.8	0.8000	0.8718	0.0295	0.8136	0.9299	-0.0718
228	0.9	0.9000	0.9447	0.0302	0.8852	1.0042	-0.0447
229	1	1.0000	1.0177	0.0313	0.9560	1.0794	-0.0177
230	1.1	1.1000	1.0906	0.0328	1.0261	1.1552	.0093615
231	1.12	1.1200	1.1309	0.0329	1.0662	1.1957	-0.0109
232	1.15	1.1500	1.1952	0.0368	1.1227	1.2678	-0.0452
233	1.2	1.2000	0.9739	0.0326	0.9097	1.0380	0.2261
234	1.3	1.3000	1.0994	0.0322	1.0360	1.1627	0.2006

SUM OF RESIDUALS	-7.99749E-13
SUM OF SQUARED RESIDUALS	12.09427
PREDICTED RESID SS (PRESS)	12.91795

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NOTE: COPYRIGHT (C) 1984,1986 SAS INSTITUTE INC., CARY, N.C.  27511, U.S.A.
NDTE: THE JOB DDIT HAS BEEN RUN UNDER RELEASE 5.16 DF SAS AT TEXAS A&M UNIVERSITY (01452001).

NDTE: CPUID   VERSION = 21  SERIAL = 172328  MDDEL = 3090 .
      CPUID   VERSION = 21  SERIAL = 272328  MDDEL = 3090 .

NDTE: SAS DPTIDNS SPECIFIED ARE:
       SORT=4

1          DATA DNE; INFILE IN1;
2          INPUT #1 SUBSID #2 T #3 A #4 AP #5 W #6 TH #7 BRHO #8 VISC #9 CYCS
3          #10 PPWS #11 LI #12 PPWP #13 VE $ #14 VPU #15 VPD;
4          PF=AP*W;
5          G=32.2;
6          GSQ=G**2;
7          RHD=3.3;
8          TSQ=T**2;
9          VDSQ=VPD**2;
10         FO=(144*PPWS*VPU*AP/(RHO*GSQ*T));
11         FA=ABS(FO);
12         F1=FA**0.33;
13         F2=SQRT(0.5*VDSQ*PF/(144*VISC**2*GSQ*TSQ*RHD));
14         IF F1 NE 0 THEN F3=LDG10(F1*CYCS);
15         ELSE F3 = 0;
16         IF F2 NE 0 THEN F4=LDG10(F2*CYCS);
17         ELSE F4 = 0;


NDTE: INFILE IN1 IS:
      DSNAME=USR.N199.AR.EXP15VAR,
      UNIT=DISK,VDL=SER=USR002,DISP=SHR,
      DCB=(BLKSIZE=6226,LRECL=22,RECFM=FB)

NDTE: 3510 LINES WERE READ FROM INFILE IN1.
NDTE: DATA SET WDRK.ONE HAS 234 DBSERVATIONS AND 27 VARIABLES. 212 DBS/TRK.
NOTE: THE DATA STATEMENT USED 0.15 SECDNDS AND 148K.

18         PRDC SDRT;
19          BY SUBSID;

NDTE: 4 CYLINDERS DYNAMICALLY ALLDCATED DN SYSDA FDR EACH DF 3 SDRT WORK DATA SETS.
NDTE: DATA SET WDRK.DNE HAS 234 DBSERVATIDNS AND 27 VARIABLES. 212 DBS/TRK.
NDTE: THE PRDCEDURE SDRT USED 0.17 SECDNDS AND 296K.

20         PRDC PRINT;
21          VAR SUBSID F1 F2 F3 F4;
NDTE: THE PRDCEDURE PRINT USED 0.10 SECONDS AND 204K AND PRINTED PAGES 1 TD 5.

22         PRDC CDRR;
23          VAR SUBSID F1 F2 F3 F4;
24         TITLE 'CORRELATIDN FOR VARIBLES: F1, F2, F3 AND F4';
NDTE: THE PROCEDURE CDRR USED 0.05 SECDNDS AND 200K AND PRINTED PAGE 6.

25         PRDC RSQUARE CP;
26          MDDEL SUBSID = F1 F2 F3 F4
27          /START=1 STDP=2;
28         TITLE2 'RSQUARE FDR REGRESSION MDDEL USING : F1,F2,F3 AND F4';
NDTE: THE PRDCEDURE RSQUARE USED 0.06 SECDNDS AND 328K AND PRINTED PAGE 7.
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29          PROC REG;
30          MODEL SUBSID = F1 F4/P CLM;
31          TITLE3 'REGRESSION MODEL USING: F1 AND F4';
32          ID SUBSID;
33          OUTPUT OUT=REGOUT P=PRED;
NOTE: ACOV AND SPEC OPTION ONLY VALID WITH RAWDATA
NOTE: THE DATA SET WORK.REGOUT HAS 234 OBSERVATIONS AND 28 VARIABLES. 204 OBS/TRK.
NOTE: THE PROCEDURE REG USED 0.15 SECONDS AND 464K AND PRINTED PAGES 8 TO 13.

34          PROC PLOT DATA=REGOUT;
35          PLOT SUBSID*PRED='*';
36          TITLE ' ACTUAL SUBSIDENCE VS PREDICTED SUBSIDENCE USING F1 AND F4';
NOTE: THE PROCEDURE PLOT USED 0.06 SECONDS AND 212K AND PRINTED PAGE 14.
NOTE: SAS USED 464K MEMORY.

NOTE: SAS INSTITUTE INC.
      SAS CIRCLE
      PO BOX 8000
      CARY, N.C. 27511-8000
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[illegible]
R-SQUARE FOR REGRESSION MODEL USING [illegible] AND [illegible]
REGRESSION MODEL USING [illegible] AND [illegible]

REGRESSION MODEL USING: F1 AND F4

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
22	0.15	0.1500	0.5671	0.0261	0.5156	0.6185	-0.4171
23	0.18	0.1800	0.4910	0.0385	0.4151	0.5670	-0.3110
24	0.2	0.2000	0.6140	0.0266	0.5616	0.6663	-0.4140
25	0.2	0.2000	0.4835	0.0298	0.4248	0.5422	-0.2835
26	0.2	0.2000	0.4992	0.0276	0.4448	0.5537	-0.2992
27	0.2	0.2000	0.4309	0.0645	0.3039	0.5580	-0.2309
28	0.2	0.2000	0.4905	0.0262	0.4388	0.5421	-0.2905
29	0.2	0.2000	0.4904	0.0507	0.3905	0.5903	-0.2904
30	0.21	0.2100	0.5471	0.0246	0.4986	0.5955	-0.3371
31	0.22	0.2200	0.5931	0.0238	0.5462	0.6401	-0.3731
32	0.22	0.2200	0.5829	0.0261	0.5314	0.6344	-0.3629
33	0.22	0.2200	0.5595	0.0272	0.5059	0.6130	-0.3395
34	0.22	0.2200	0.5913	0.0235	0.5450	0.6375	-0.3713
35	0.25	0.2500	0.6458	0.0229	0.6008	0.6909	-0.3958
36	0.25	0.2500	0.6720	0.0225	0.6275	0.7164	-0.4220
37	0.3	0.3000	0.5701	0.0237	0.5234	0.6169	-0.2701
38	0.3	0.3000	0.7293	0.0261	0.6778	0.7809	-0.4293
39	0.3	0.3000	0.5805	0.0282	0.5249	0.6362	-0.2805
40	0.3	0.3000	0.6731	0.0260	0.6219	0.7242	-0.3731
41	0.3	0.3000	0.6344	0.0244	0.5864	0.6824	-0.3344
42	0.3	0.3000	0.6915	0.0214	0.6492	0.7337	-0.3915
43	0.3	0.3000	0.7396	0.0208	0.6985	0.7806	-0.4396
44	0.32	0.3200	0.6007	0.0300	0.5417	0.6597	-0.2807
45	0.35	0.3500	0.6793	0.0454	0.5899	0.7688	-0.3293
46	0.35	0.3500	0.7401	0.0208	0.6992	0.7810	-0.3901
47	0.38	0.3800	0.7273	0.0238	0.6804	0.7742	-0.3473
48	0.38	0.3800	0.7936	0.0200	0.7541	0.8331	-0.4136
49	0.4	0.4000	0.5962	0.0284	0.5402	0.6522	-0.1962
50	0.4	0.4000	0.6146	0.0276	0.5601	0.6690	-0.2146
51	0.4	0.4000	0.7538	0.0215	0.7115	0.7961	-0.3538
52	0.4	0.4000	0.8436	0.0203	0.8036	0.8837	-0.4436
53	0.4	0.4000	0.7611	0.0199	0.7219	0.8003	-0.3611
54	0.4	0.4000	0.7203	0.0365	0.6483	0.7923	-0.3203
55	0.45	0.4500	0.7898	0.0236	0.7433	0.8363	-0.3398
56	0.45	0.4500	0.6786	0.0272	0.6251	0.7322	-0.2286
57	0.45	0.4500	0.8403	0.0217	0.7976	0.8830	-0.3903
58	0.48	0.4800	0.8368	0.0198	0.7977	0.8758	-0.3568
59	0.5	0.5000	0.7434	0.0202	0.7035	0.7832	-0.2434
60	0.5	0.5000	0.7144	0.0279	0.6594	0.7694	-0.2144
61	0.5	0.5000	0.8179	0.0259	0.7669	0.8689	-0.3179
62	0.5	0.5000	0.7088	0.0272	0.6552	0.7624	-0.2088
63	0.5	0.5000	0.9143	0.0200	0.8750	0.9536	-0.4143
64	0.5	0.5000	0.8376	0.0237	0.7909	0.8843	-0.3376
65	0.5	0.5000	0.7595	0.0457	0.6694	0.8497	-0.2595
66	0.5	0.5000	0.7824	0.0208	0.7414	0.8234	-0.2824
67	0.52	0.5200	0.8204	0.0215	0.7779	0.8628	-0.3004

REGRESSION MODEL USING: F1 AND F4

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
68	0.52	0.5200	0.8694	0.0197	0.8306	0.9082	-0.3494
69	0.52	0.5200	0.7925	0.0378	0.7180	0.8670	-0.2725
70	0.55	0.5500	0.8474	0.0211	0.8059	0.8889	-0.2974
71	0.55	0.5500	0.8846	0.0199	0.8454	0.9238	-0.3346
72	0.6	0.6000	0.8777	0.0258	0.8270	0.9285	-0.2777
73	0.6	0.6000	0.8298	0.0277	0.7753	0.8843	-0.2298
74	0.6	0.6000	0.9715	0.0201	0.9319	1.0111	-0.3715
75	0.6	0.6000	0.8390	0.0235	0.7928	0.8852	-0.2390
76	0.6	0.6000	0.9046	0.0190	0.8671	0.9422	-0.3046
77	0.6	0.6000	0.8485	0.0214	0.8063	0.8907	-0.2485
78	0.6	0.6000	0.9007	0.0198	0.8617	0.9398	-0.3007
79	0.65	0.6500	0.8934	0.0201	0.8537	0.9330	-0.2434
80	0.65	0.6500	0.8430	0.0198	0.8040	0.8819	-0.1930
81	0.67	0.6700	0.8642	0.0199	0.8249	0.9034	-0.1942
82	0.7	0.7000	0.8563	0.0203	0.8163	0.8963	-0.1563
83	0.7	0.7000	0.8343	0.0284	0.7785	0.8902	-0.1343
84	0.7	0.7000	0.8796	0.0282	0.8240	0.9351	-0.1796
85	0.7	0.7000	1.0128	0.0203	0.9728	1.0529	-0.3128
86	0.7	0.7000	0.9526	0.0265	0.9004	1.0048	-0.2526
87	0.7	0.7000	0.7265	0.0226	0.6819	0.7710	-0.0265
88	0.7	0.7000	0.8167	0.0474	0.7233	0.9101	-0.1167
89	0.7	0.7000	0.9362	0.0196	0.8976	0.9748	-0.2362
90	0.7	0.7000	0.9372	0.0207	0.8964	0.9780	-0.2372
91	0.7	0.7000	0.8456	0.0401	0.7666	0.9246	-0.1456
92	0.72	0.7200	0.9642	0.0264	0.9121	1.0163	-0.2442
93	0.75	0.7500	0.9152	0.0292	0.8577	0.9728	-0.1652
94	0.75	0.7500	0.9445	0.0205	0.9041	0.9849	-0.1945
95	0.75	0.7500	0.7358	0.0240	0.6885	0.7830	0.0142
96	0.75	0.7500	0.9755	0.0209	0.9343	1.0166	-0.2255
97	0.77	0.7700	0.9910	0.0269	0.9380	1.0440	-0.2210
98	0.8	0.8000	0.9767	0.0305	0.9166	1.0369	-0.1767
99	0.8	0.8000	0.9482	0.0240	0.9009	0.9956	-0.1482
100	0.8	0.8000	0.9348	0.0293	0.8770	0.9926	-0.1348
101	0.8	0.8000	1.0844	0.0223	1.0404	1.1285	-0.2844
102	0.8	0.8000	0.8602	0.0480	0.7657	0.9547	-0.0602
103	0.8	0.8000	0.9926	0.0211	0.9510	1.0341	-0.1926
104	0.8	0.8000	0.9657	0.0218	0.9227	1.0087	-0.1657
105	0.8	0.8000	0.9262	0.0358	0.8557	0.9966	-0.1262
106	0.82	0.8200	1.0065	0.0213	0.9645	1.0485	-0.1865
107	0.85	0.8500	1.0240	0.0315	0.9619	1.0861	-0.1740
108	0.85	0.8500	0.9933	0.0214	0.9511	1.0355	-0.1433
109	0.85	0.8500	1.0204	0.0276	0.9659	1.0748	-0.1704
110	0.85	0.8500	0.9977	0.0199	0.9586	1.0369	-0.1477
111	0.88	0.8800	1.0225	0.0215	0.9801	1.0649	-0.1425
112	0.9	0.9000	0.9051	0.0195	0.8668	0.9435	-.005148
113	0.9	0.9000	1.0359	0.0315	0.9737	1.0980	-0.1359

REGRESSION MODEL USING 'F1' AND 'F4'

CORRELATION FOR VARIBLES: F1, F2, F3 AND F4

REGRESSION MODEL USING: F1 AND F4

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
114	0.9	0.9000	0.9818	0.0245	0.9335	1.0300	-0.0818
115	0.9	0.9000	0.9700	0.0298	0.9113	1.0288	-0.0700
116	0.9	0.9000	1.0932	0.0219	1.0501	1.1363	-0.1932
117	0.9	0.9000	0.8636	0.0202	0.8237	0.9035	0.0364
118	0.9	0.9000	0.8955	0.0487	0.7996	0.9915	.0044547
119	0.9	0.9000	1.0349	0.0218	0.9921	1.0778	-0.1349
120	0.9	0.9000	0.9347	0.0215	0.8924	0.9771	-0.0347
121	0.9	0.9000	0.9634	0.0365	0.8915	1.0353	-0.0634
122	0.95	0.9500	1.0639	0.0303	1.0043	1.1236	-0.1139
123	0.95	0.9500	1.0366	0.0209	0.9955	1.0777	-0.0866
124	1	1.0000	0.9328	0.0205	0.8924	0.9732	0.0672
125	1	1.0000	1.0993	0.0331	1.0341	1.1645	-0.0993
126	1	1.0000	0.9474	0.0279	0.8923	1.0024	0.0526
127	1	1.0000	1.0100	0.0307	0.9496	1.0705	-0.0100
128	1	1.0000	1.0468	0.0223	1.0029	1.0907	-0.0468
129	1	1.0000	1.1527	0.0240	1.1054	1.1999	-0.1527
130	1	1.0000	1.0763	0.0305	1.0162	1.1365	-0.0763
131	1	1.0000	0.8867	0.0204	0.8466	0.9268	0.1133
132	1	1.0000	0.9253	0.0495	0.8278	1.0229	0.0747
133	1	1.0000	1.0108	0.0202	0.9710	1.0506	-0.0108
134	1	1.0000	0.9949	0.0373	0.9214	1.0683	.0051384
135	1.01	1.0100	1.0586	0.0213	1.0167	1.1006	-0.0486
136	1.02	1.0200	1.0737	0.0217	1.0309	1.1165	-0.0537
137	1.02	1.0200	1.1214	0.0223	1.0775	1.1653	-0.1014
138	1.02	1.0200	1.1220	0.0226	1.0774	1.1666	-0.1020
139	1.02	1.0200	1.0860	0.0308	1.0254	1.1466	-0.0660
140	1.03	1.0300	1.0990	0.0231	1.0534	1.1446	-0.0690
141	1.05	1.0500	1.0961	0.0310	1.0350	1.1571	-0.0461
142	1.05	1.0500	1.0361	0.0206	0.9955	1.0767	0.0139
143	1.08	1.0800	1.1058	0.0312	1.0443	1.1673	-0.0258
144	1.08	1.0800	1.0219	0.0203	0.9819	1.0619	0.0581
145	1.08	1.0800	1.0950	0.0221	1.0514	1.1385	-0.0150
146	1.1	1.1000	0.9739	0.0210	0.9326	1.0152	0.1261
147	1.1	1.1000	1.1326	0.0339	1.0658	1.1994	-0.0326
148	1.1	1.1000	1.0114	0.0283	0.9557	1.0672	0.0886
149	1.1	1.1000	1.0585	0.0320	0.9955	1.1215	0.0415
150	1.1	1.1000	1.0657	0.0225	1.0213	1.1101	0.0343
151	1.1	1.1000	1.0921	0.0236	1.0456	1.1386	0.007922
152	1.1	1.1000	1.3002	0.0278	1.2454	1.3551	-0.2002
153	1.1	1.1000	1.1145	0.0314	1.0526	1.1765	-0.0145
154	1.1	1.1000	0.9853	0.0455	0.8957	1.0749	0.1147
155	1.1	1.1000	1.1034	0.0223	1.0595	1.1473	-.003368
156	1.1	1.1000	1.0366	0.0214	0.9945	1.0786	0.0634
157	1.1	1.1000	1.0221	0.0381	0.9470	1.0973	0.0779
158	1.12	1.1200	1.1248	0.0228	1.0798	1.1698	-.004771
159	1.12	1.1200	1.0451	0.0382	0.9698	1.1203	0.0749

REGRESSION MODEL USING: F1 AND F4

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
160	1.15	1.1500	0.9819	0.0216	0.9394	1.0244	0.1681
161	1.15	1.1500	1.0427	0.0315	0.9807	1.1047	0.1073
162	1.15	1.1500	1.1250	0.0244	1.0770	1.1731	0.0250
163	1.15	1.1500	1.1318	0.0319	1.0690	1.1946	0.0182
164	1.15	1.1500	1.1132	0.0225	1.0689	1.1575	0.0368
165	1.15	1.1500	1.1328	0.0230	1.0874	1.1781	0.0172
166	1.15	1.1500	1.0797	0.0215	1.0374	1.1220	0.0703
167	1.15	1.1500	1.0874	0.0358	1.0168	1.1579	0.0626
168	1.18	1.1800	1.1405	0.0232	1.0948	1.1863	0.0395
169	1.18	1.1800	1.1464	0.0234	1.1004	1.1925	0.0336
170	1.2	1.2000	1.0154	0.0225	0.9711	1.0597	0.1846
171	1.2	1.2000	1.0590	0.0277	1.0045	1.1135	0.1410
172	1.2	1.2000	1.0304	0.0312	0.9690	1.0919	0.1696
173	1.2	1.2000	1.1073	0.0238	1.0605	1.1542	0.0927
174	1.2	1.2000	1.1418	0.0321	1.0786	1.2050	0.0582
175	1.2	1.2000	1.0029	0.0200	0.9634	1.0424	0.1971
176	1.2	1.2000	1.0084	0.0463	0.9171	1.0996	0.1916
177	1.2	1.2000	1.1541	0.0236	1.1076	1.2005	0.0459
178	1.2	1.2000	1.0091	0.0410	0.9283	1.0900	0.1909
179	1.21	1.2100	1.1699	0.0240	1.1226	1.2171	0.0401
180	1.25	1.2500	1.1830	0.0349	1.1142	1.2518	0.0670
181	1.25	1.2500	1.0716	0.0322	1.0082	1.1351	0.1784
182	1.25	1.2500	1.0772	0.0323	1.0135	1.1409	0.1728
183	1.25	1.2500	1.1576	0.0325	1.0935	1.2216	0.0924
184	1.25	1.2500	1.0287	0.0467	0.9368	1.1207	0.2213
185	1.3	1.3000	1.0383	0.0215	0.9960	1.0806	0.2617
186	1.3	1.3000	1.1016	0.0284	1.0456	1.1575	0.1984
187	1.3	1.3000	1.1505	0.0249	1.1014	1.1996	0.1495
188	1.3	1.3000	1.1953	0.0280	1.1402	1.2503	0.1047
189	1.3	1.3000	1.1725	0.0329	1.1077	1.2373	0.1275
190	1.3	1.3000	1.0421	0.0209	1.0010	1.0833	0.2579
191	1.3	1.3000	1.1114	0.0333	1.0459	1.1770	0.1886
192	1.35	1.3500	1.2074	0.0338	1.1407	1.2741	0.1426
193	1.35	1.3500	1.1867	0.0333	1.1211	1.2523	0.1633
194	1.35	1.3500	0.9336	0.0535	0.8281	1.0391	0.4164
195	1.4	1.4000	1.1266	0.0291	1.0693	1.1839	0.2734
196	1.4	1.4000	1.2003	0.0337	1.1339	1.2666	0.1997
197	1.4	1.4000	0.9867	0.0200	0.9472	1.0261	0.4133
198	1.4	1.4000	1.0100	0.0453	0.9206	1.0993	0.3900
199	1.45	1.4500	1.0836	0.0225	1.0392	1.1279	0.3664
200	1.45	1.4500	1.2155	0.0343	1.1479	1.2831	0.2345
201	1.5	1.5000	1.1156	0.0233	1.0696	1.1616	0.3844
202	1.5	1.5000	1.2484	0.0352	1.1790	1.3178	0.2516
203	1.5	1.5000	1.1585	0.0299	1.0996	1.2173	0.3415
204	1.5	1.5000	1.0591	0.0213	1.0172	1.1011	0.4409
205	1.5	1.5000	1.0257	0.0461	0.9348	1.1166	0.4743

REGRESSION MODEL USING: F1 AND F4

REGRESSION MODEL USING: F1 AND F4

OBS	ID	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% MEAN	UPPER95% MEAN	RESIDUAL
206	1.55	1.5500	1.1972	0.0295	1.1390	1.2553	0.3528
207	1.55	1.5500	1.1359	0.0237	1.0891	1.1827	0.4141
208	1.55	1.5500	1.0157	0.0499	0.9174	1.1139	0.5343
209	1.6	1.6000	1.1712	0.0250	1.1219	1.2206	0.4288
210	1.6	1.6000	1.2838	0.0368	1.2114	1.3563	0.3162
211	1.6	1.6000	1.3288	0.0407	1.2487	1.4089	0.2712
212	1.6	1.6000	1.2279	0.0302	1.1684	1.2874	0.3721
213	1.6	1.6000	1.0855	0.0301	1.0261	1.1448	0.5145
214	1.6	1.6000	1.2067	0.0321	1.1435	1.2700	0.3933
215	1.6	1.6000	1.0710	0.0445	0.9834	1.1587	0.5290
216	1.62	1.6200	1.1719	0.0243	1.1241	1.2197	0.4481
217	1.65	1.6500	1.2120	0.0263	1.1601	1.2639	0.4380
218	1.65	1.6500	1.2422	0.0306	1.1819	1.3026	0.4078
219	1.65	1.6500	1.3150	0.0294	1.2571	1.3728	0.3350
220	1.65	1.6500	1.1684	0.0237	1.1217	1.2151	0.4816
221	1.65	1.6500	1.0716	0.0595	0.9543	1.1888	0.5784
222	1.7	1.7000	1.3417	0.0397	1.2635	1.4200	0.3583
223	1.7	1.7000	1.3726	0.0421	1.2895	1.4556	0.3274
224	1.7	1.7000	1.3273	0.0298	1.2686	1.3860	0.3727
225	1.7	1.7000	1.3476	0.0304	1.2877	1.4074	0 3524
226	1.7	1.7000	1.2698	0.0281	1.2144	1.3251	C.4302
227	1.72	1.7200	1.2205	0.0260	1.1692	1.2718	0.4995
228	1.75	1.7500	1.2484	0.0275	1.1942	1.3026	0.5016
229	1.75	1.7500	1.2419	0.0284	1.1859	1.2979	0.5081
230	1.75	1.7500	1.3582	0.0308	1.2976	1.4189	0.3918
231	1.75	1.7500	1.3672	0.0311	1.3060	1.4284	0.3828
232	1.8	1.8000	1.2399	0.0266	1.1875	1.2924	0.5601
233	1.8	1.8000	1.3770	0.0314	1.3150	1.4389	0.4230
234	1.8	1.8000	1.3851	0.0317	1.3227	1.4476	0.4149

SUM OF RESIDUALS -1.07736E-12
SUM OF SQUARED RESIDUALS 19.43494
PREDICTED.RESID SS (PRESS) 20.24222

VITA

Alvin Eugene Grimmig Jr. was born on May 24, 1951 in Miami Beach, Florida of Alvin and Nora Grimmig Sr. He married Miss Debra Kay Rademacher on May 6, 1972. He enlisted in the Navy in June 1972 and received a commission in Civil Engineer Corps in 1978. He received a baccalaureate degree in ocean engineering from the University of Washington located in Seattle, Washington in December of 1978.

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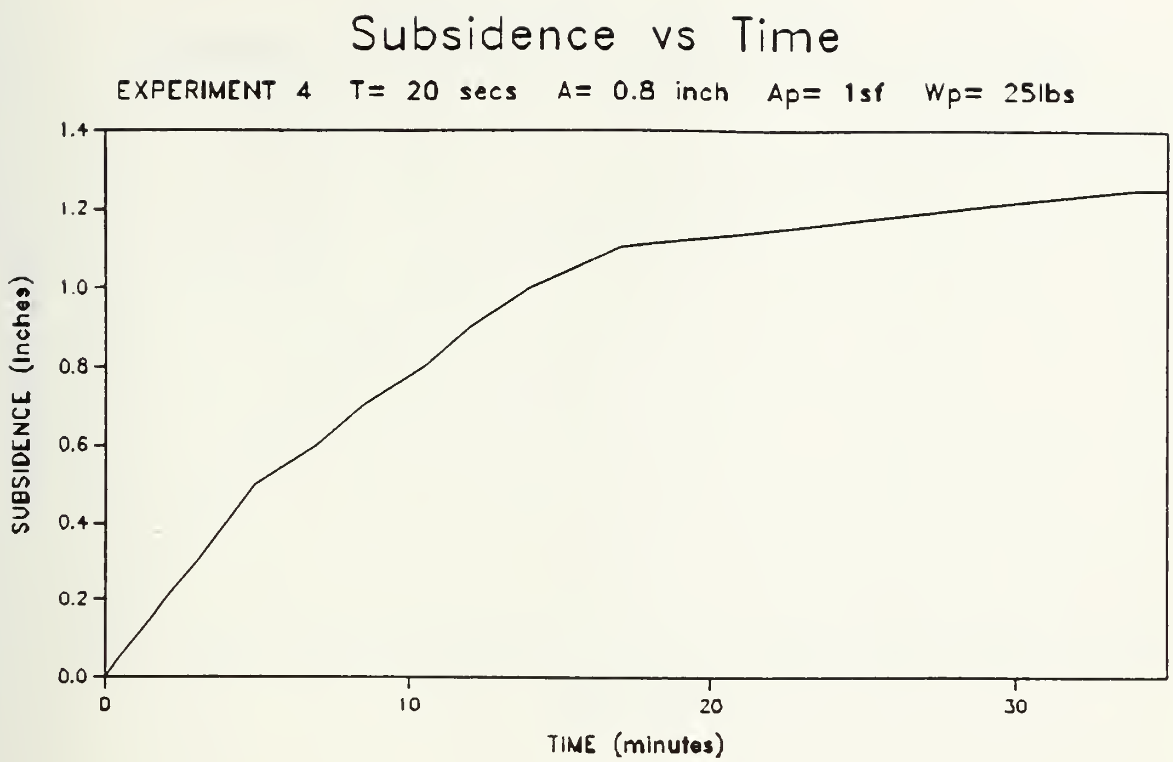

Subsidence vs Time
EXPERIMENT 4 T= 20 secs A= 0.8 inch Ap= 1sf Wp= 25lbs
SUBSIDENCE (inches)
TIME (minutes)

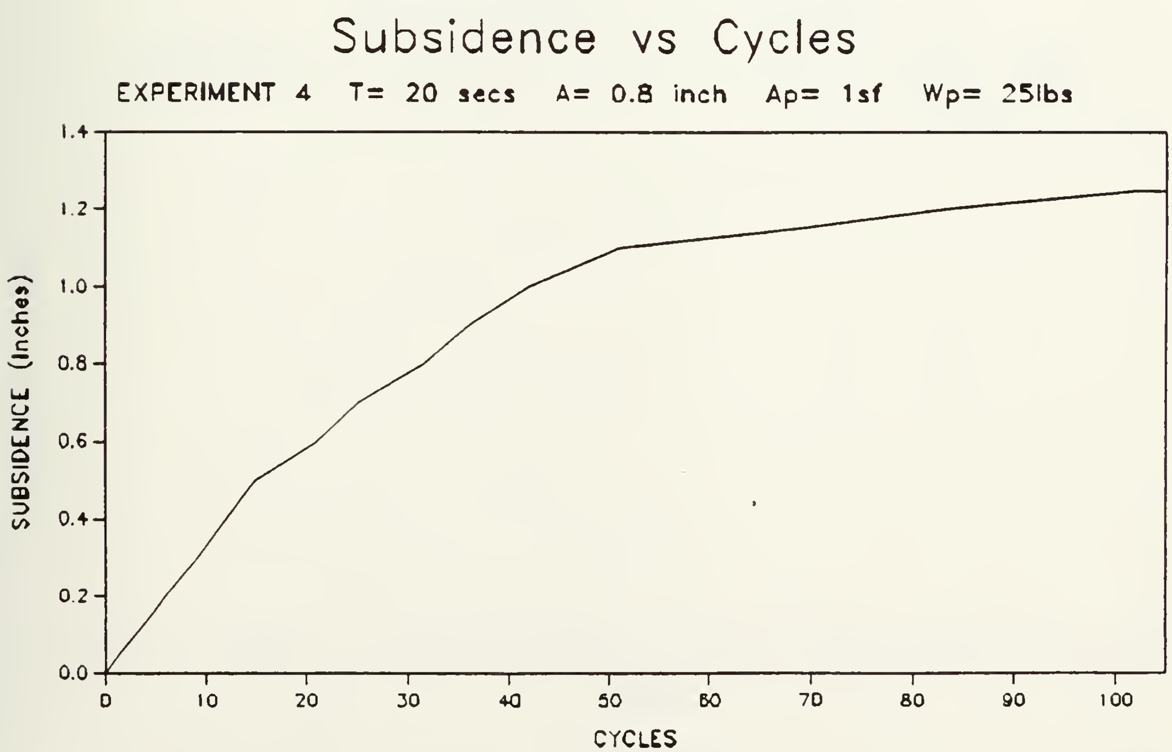
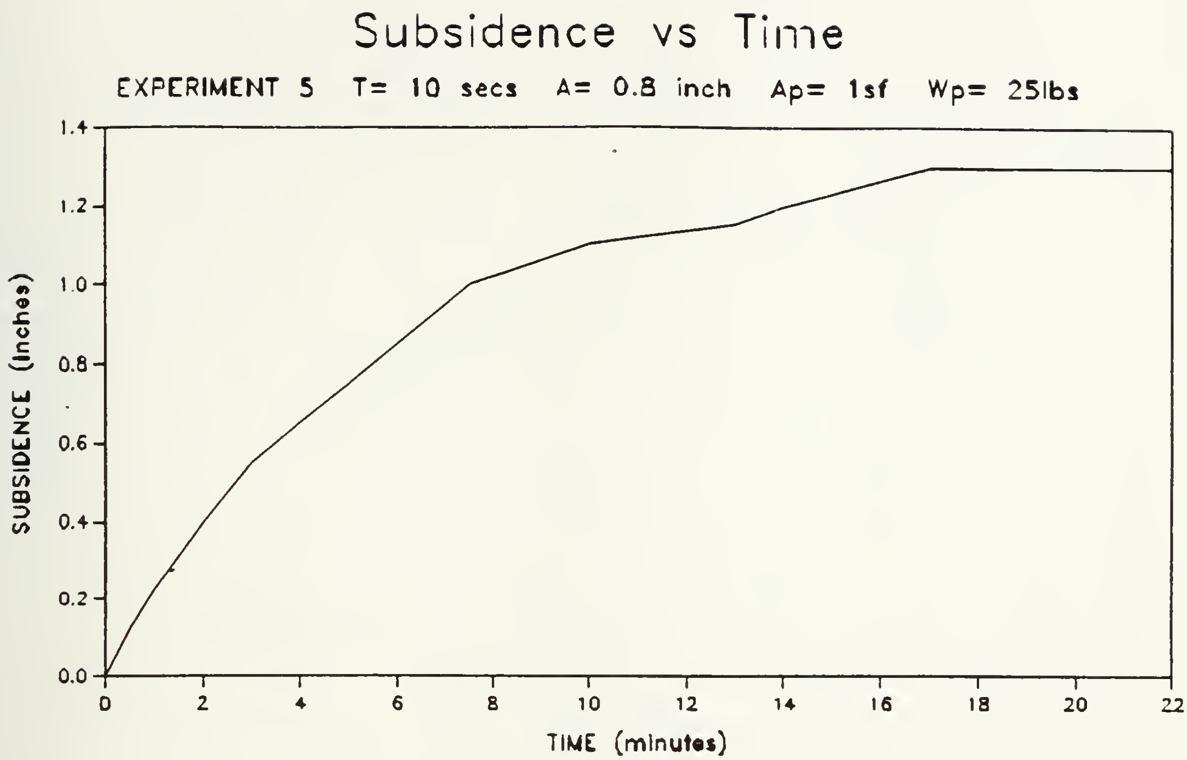
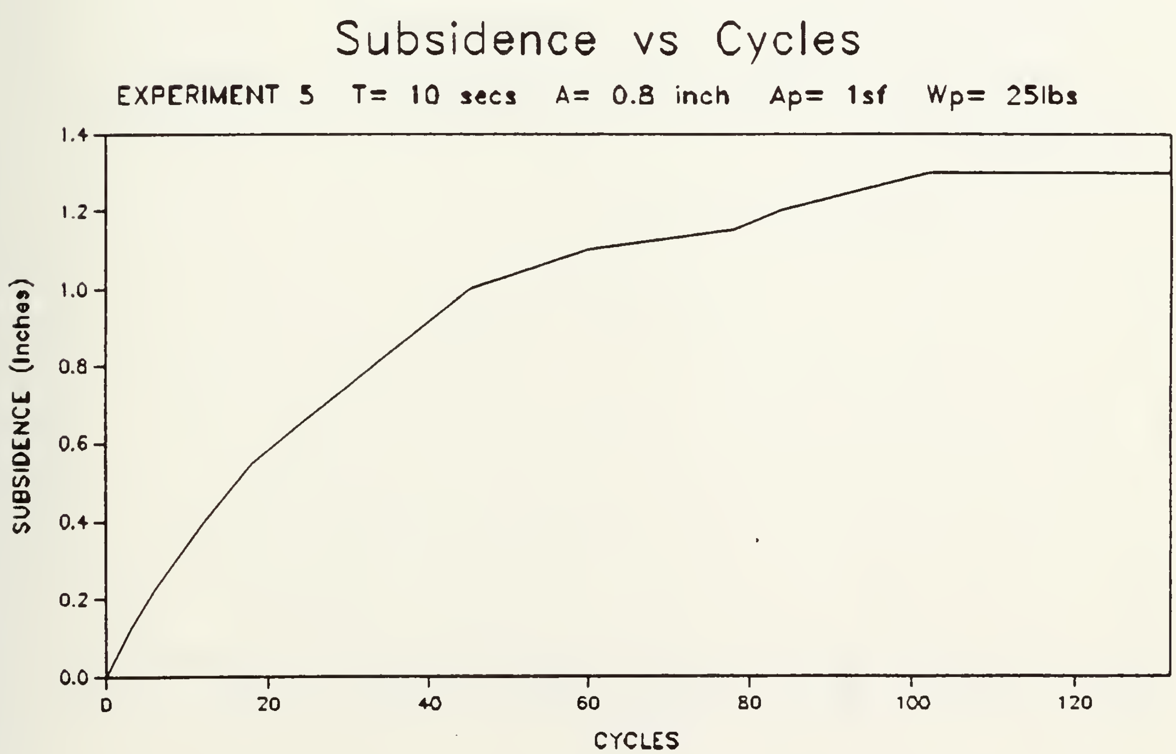

Subsidence vs Cycles
EXPERIMENT 4 T= 20 secs A= 0.8 inch Ap= 1sf Wp= 25lbs
SUBSIDENCE (inches)
CYCLES

FIGURE 4

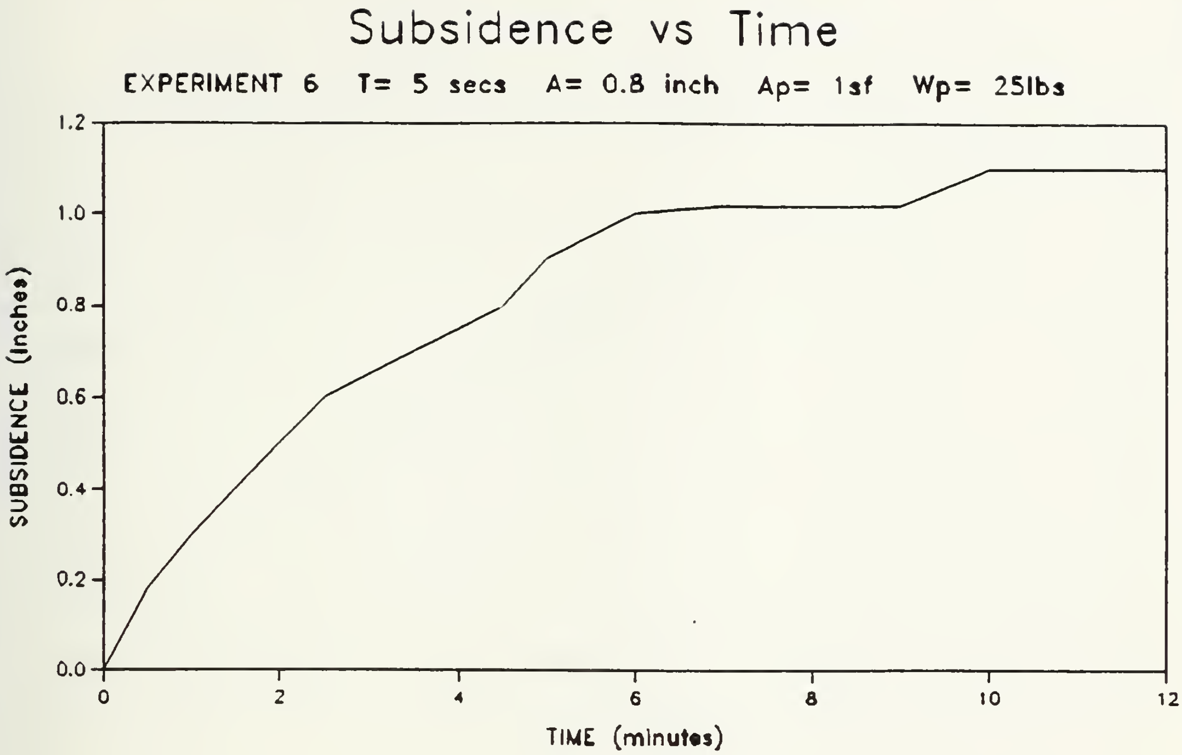


Subsidence vs Time
EXPERIMENT 5 T= 10 secs A= 0.8 inch Ap= 1sf Wp= 25lbs
SUBSIDENCE (Inches)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0 2 4 6 8 10 12 14 16 18 20 22
TIME (minutes)

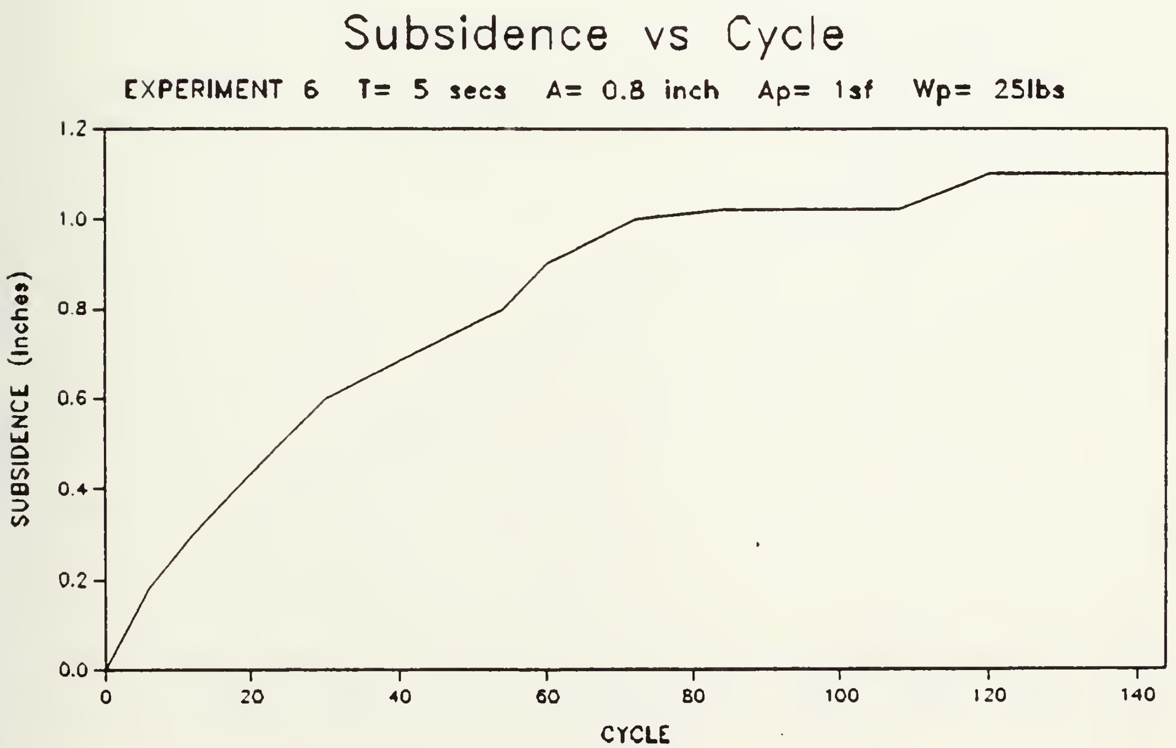


Subsidence vs Cycles
EXPERIMENT 5 T= 10 secs A= 0.8 inch Ap= 1sf Wp= 25lbs
SUBSIDENCE (Inches)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0 20 40 60 80 100 120
CYCLES

FIGURE 5

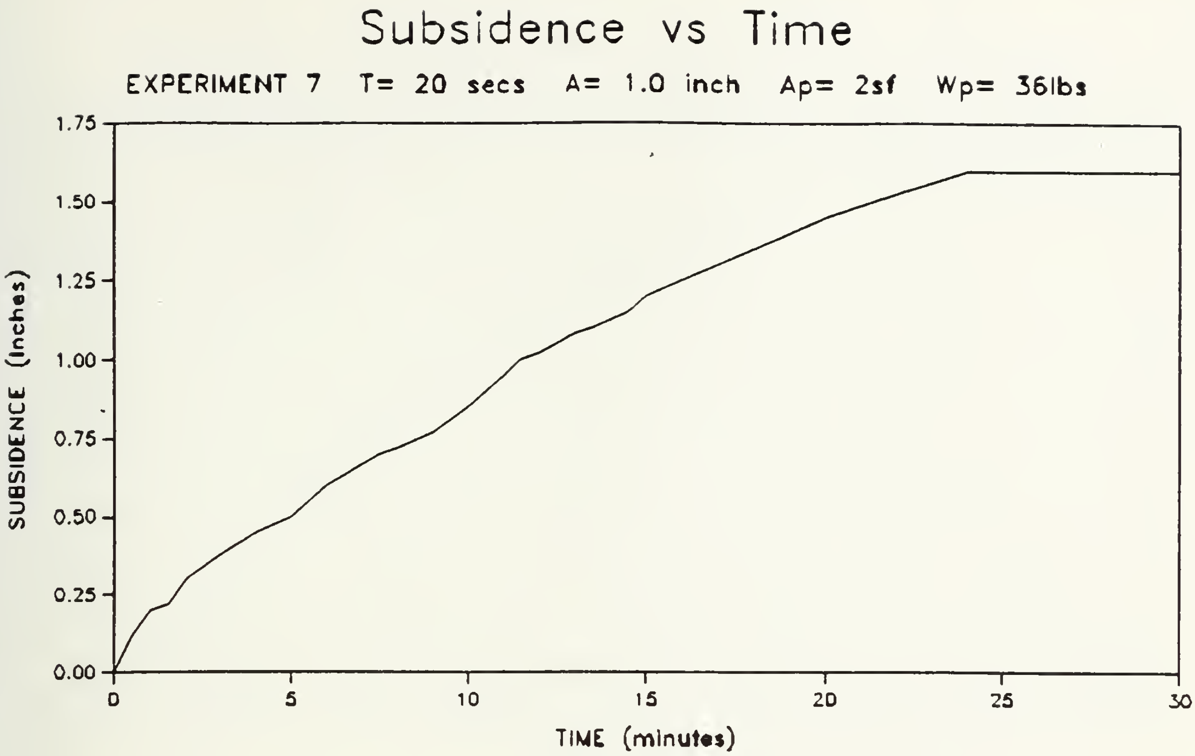


Subsidence vs Time
EXPERIMENT 6 T= 5 secs A= 0.8 inch Ap= 1sf Wp= 25lbs
SUBSIDENCE (inches)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
12
TIME (minutes)



Subsidence vs Cycle
EXPERIMENT 6 T= 5 secs A= 0.8 inch Ap= 1sf Wp= 25lbs
SUBSIDENCE (inches)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
120
140
CYCLE

FIGURE 6


Subsidence vs Time
EXPERIMENT 7 T= 20 secs A= 1.0 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (Inches)
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
5
10
15
20
25
30
TIME (minutes)

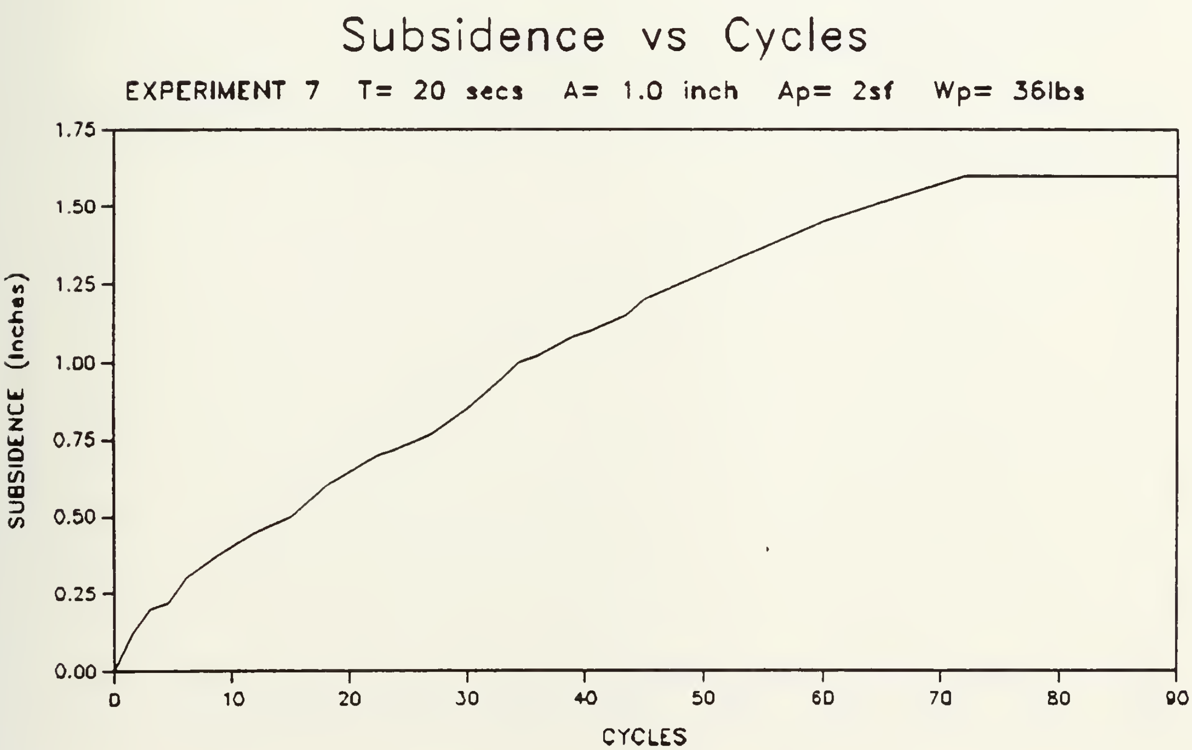
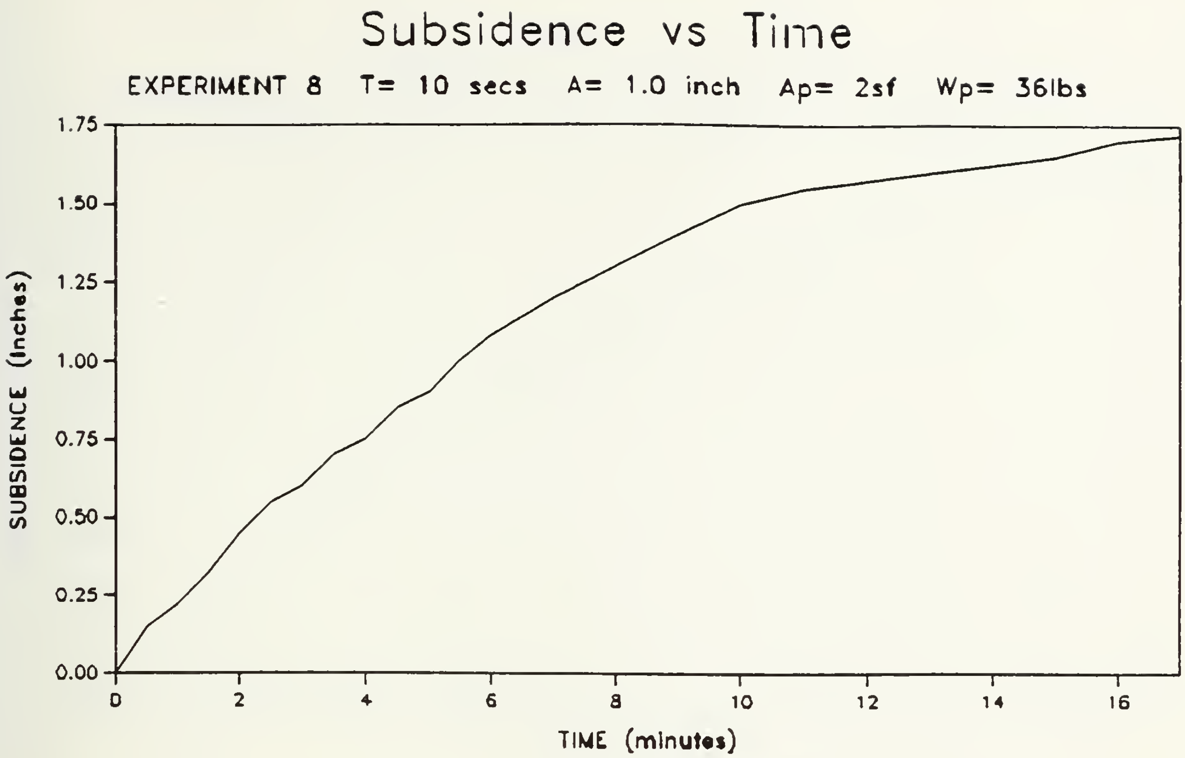

Subsidence vs Cycles
EXPERIMENT 7 T= 20 secs A= 1.0 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (Inches)
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
10
20
30
40
50
60
70
80
90
CYCLES

FIGURE 7


Subsidence vs Time
EXPERIMENT 8 T= 10 secs A= 1.0 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (inches)
TIME (minutes)
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
2
4
6
8
10
12
14
16

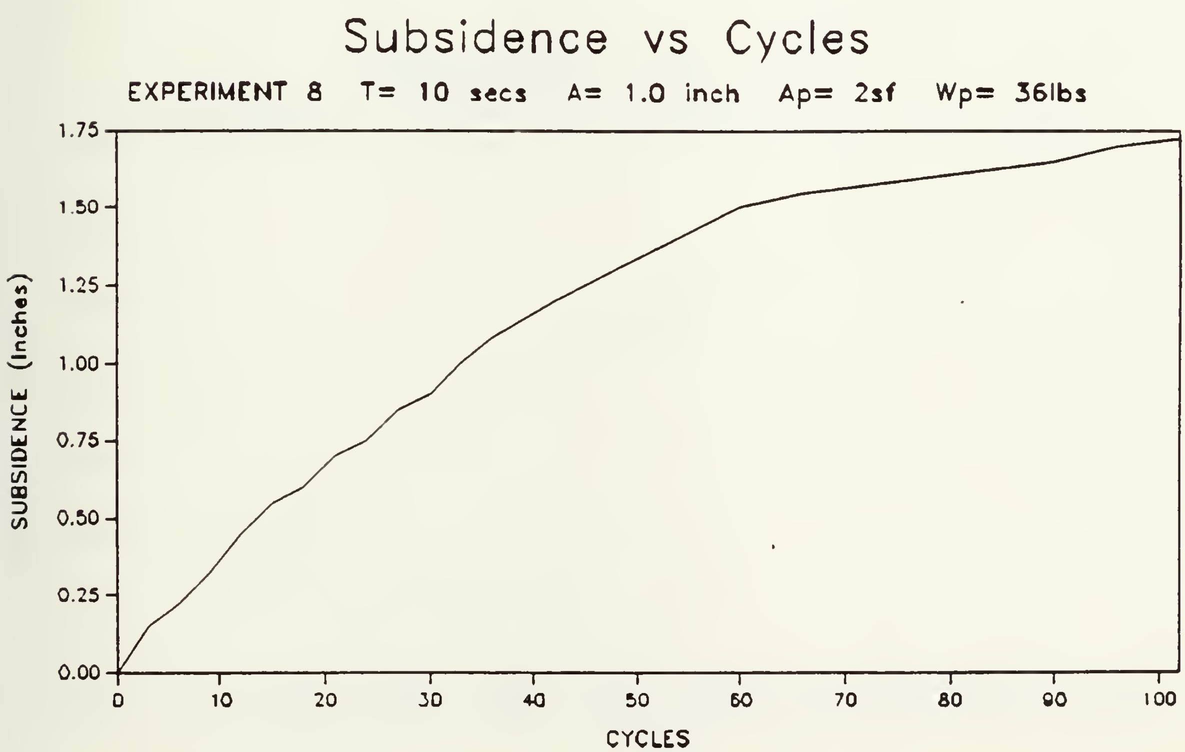
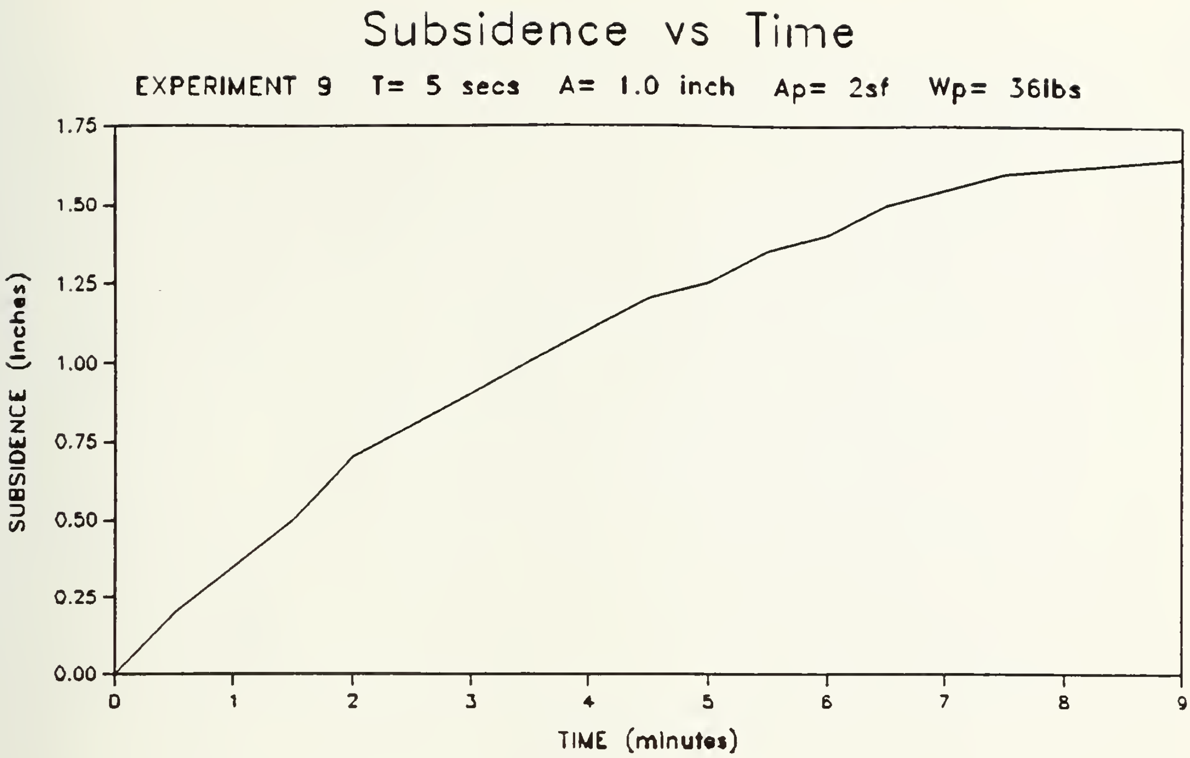

Subsidence vs Cycles
EXPERIMENT 8 T= 10 secs A= 1.0 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (inches)
CYCLES
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
10
20
30
40
50
60
70
80
90
100

FIGURE 8


Subsidence vs Time
EXPERIMENT 9 T= 5 secs A= 1.0 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (Inches)
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
1
2
3
4
5
6
7
8
9
TIME (minutes)

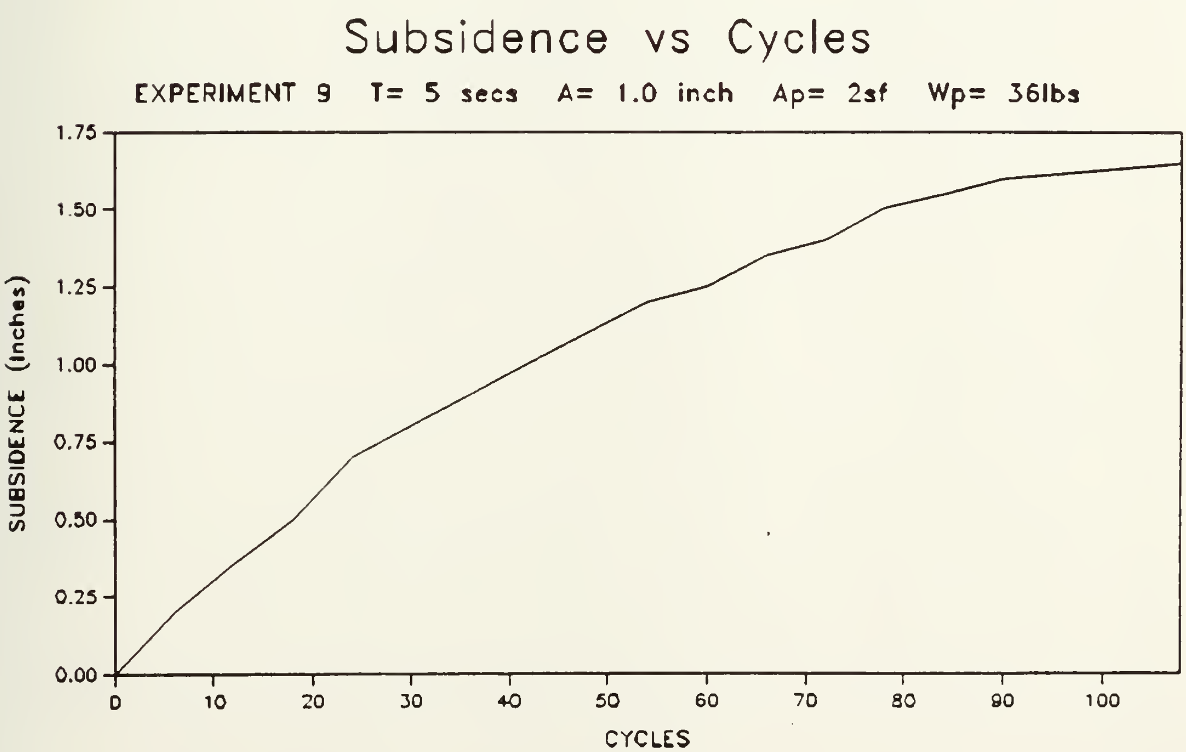

Subsidence vs Cycles
EXPERIMENT 9 T= 5 secs A= 1.0 inch Ap= 2sf Wp= 36lbs
SUBSIDENCE (Inches)
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
10
20
30
40
50
60
70
80
90
100
CYCLES

FIGURE 9

Thesis
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c.1 Pumping-erosion subidence of a seafloor plate-footing.